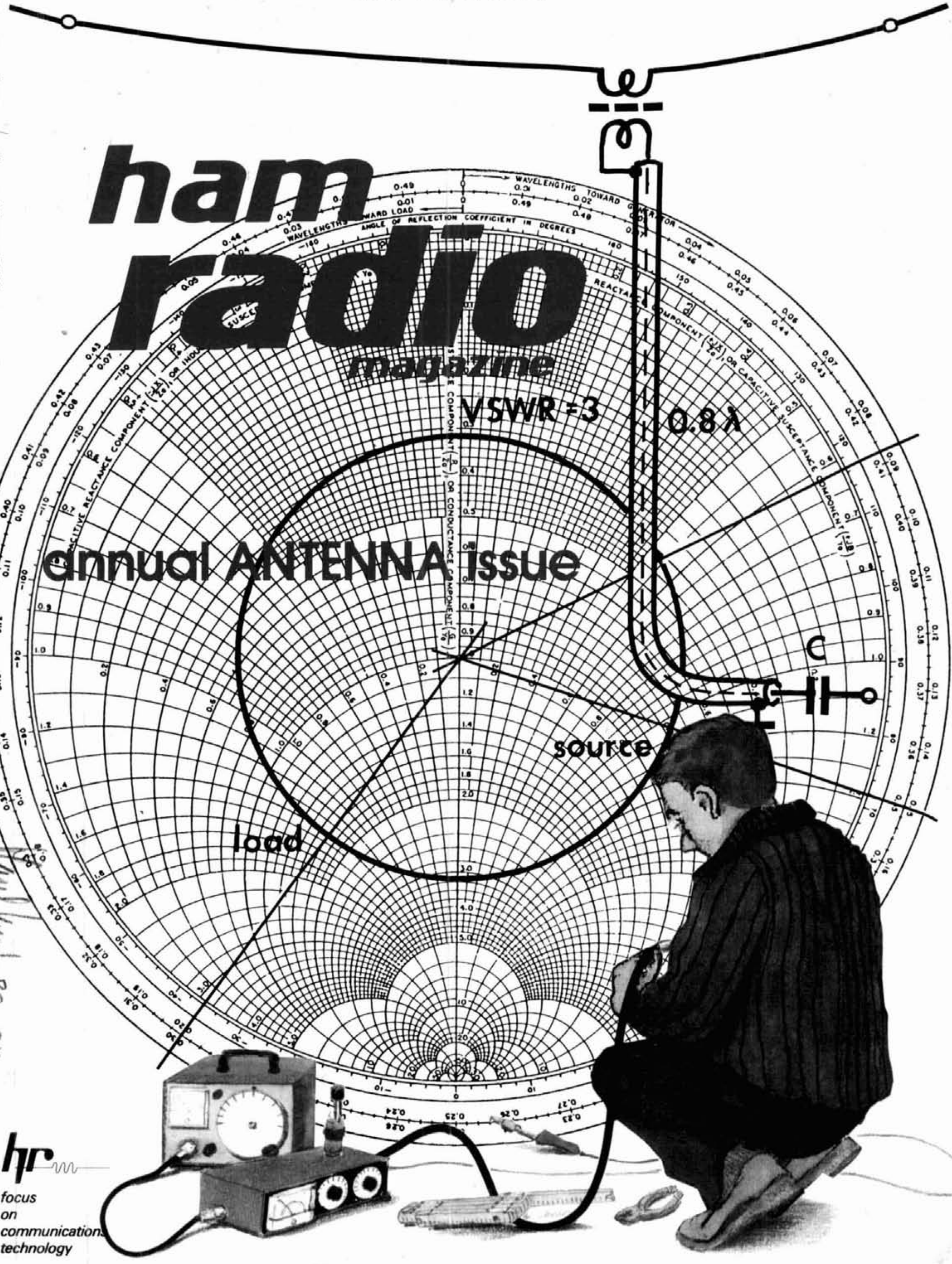
MAY 1988 / $2.50

ham radio magazine

annual ANTENNA issue



hr

focus
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THE ALL NEW PRIVATE PATCH IV BY CSI HAS MORE COMMUNICATIONS POWER THAN EVER BEFORE

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- NEW! **Telephone initiated control . . .**
  - ✓ **Operate your base station with complete control from any telephone**
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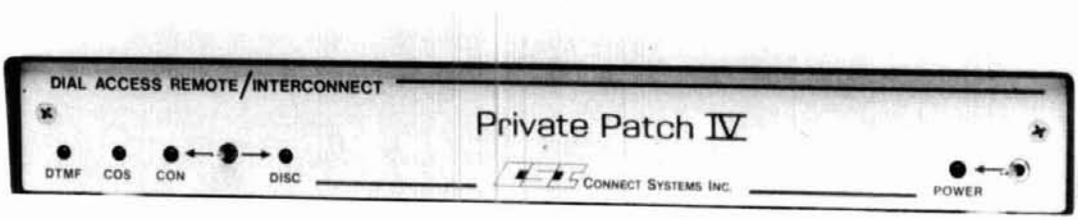

The new telephone initiated control capabilities are awesome. Imagine having full use and full control of your base station radio operating straight simplex or through any repeater *from any telephone!* From your desk at the office, from a pay phone, from a hotel room, etc. You can even change the operating channel from the touchpad!

Our digital VOX processor flips your conversation back and forth fully automatically. There are no buttons to press as in phone remote devices. And you are in full control 100% of the time!

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Private Patch IV will be your most important investment in communications.

✓ 176

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- • Secret toll override code
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- • Activity timer
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- • Ringout
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- • Busy channel ringout inhibit
- ✓ Status messages
- ✓ Internally squelched audio
- • MOV lightning protection
- ✓ Front panel status led's
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- ✓ 24 dip switches make all features user programmable/selectable.

- ■ Connects to MIC and ext. speaker jack on *any* radio. Or connect internally if desired.
- ■ Can be connected to any HT. (Even those with a two wire interface.)
- ■ Can be operated simplex, through a repeater from a base station or connected directly to a repeater for semi-duplex operation.
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- ■ Made in U.S.A.

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ham radio

magazine

MAY 1988

volume 21, number 5

contents

ham radio magazine is published monthly by
Communications Technology, Inc.
Greenville, New Hampshire 03048-0498
Telephone 603 878 1441

subscription rates

United States:
one year, $22.95; two years, $38.95, three years, $49.95
Europe (via KLM air mail), $40.00
Canada, Japan, South Africa and other countries (via surface mail),
one year, $31.00; two years, $55.00; three years, $74.00

All subscription orders payable in U.S. funds, via international
postal money order or check drawn on U.S. bank

international subscription agents: page 101

Microfilm copies are available from
University Microfilms, International
Ann Arbor, Michigan 48106
Order publication number 3076

Cassette tapes of selected articles from *ham radio*
are available to the blind and physically handicapped
from Recorded Periodicals,
919 Walnut Street, Philadelphia, Pennsylvania 19107

Second class postage paid
at Greenville, New Hampshire 03048-0498
and at additional mailing offices
ISSN 0148-5989

Send change of address to *ham radio*
Greenville, New Hampshire 03048-0498

REFLECTIONS

changes

Like the regeneration and change that come every spring, *ham radio* is feeling the first stirrings of new life.

Over the long winter months we've been listening to you. Your comments in letters to the editor, phone conversations, and on the bands, have been carefully gathered and mulled over by those of us who bring you the magazine *you* want to read.

Our readers are as varied as Amateur Radio itself. There are the Novices, just learning the language and venturing to build that first rig. There are the old-timers with many hours on the air and tons of experience putting together special homebrew projects. Some of you have highly technical backgrounds and want to know all the theory behind everything you undertake. Others — into Amateur Radio just for the fun of it — simply want to build something that works.

A lot of you say *ham radio* is just the magazine you're looking for. Many readers are hooked on the new technology and, with the articles offered in *HR*, are busy devising new setups. Others lament the proliferation of digital articles, and are nostalgic for the days when computers were big machines that took up entire buildings and certainly wouldn't fit in the ham shack!

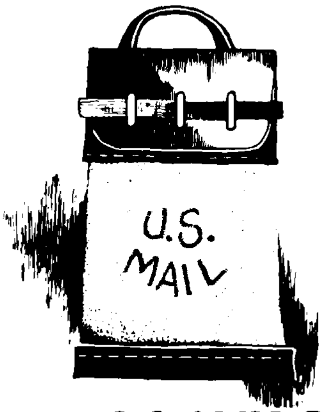
This magazine is for *you* and we need *your* help to keep it that way. Write to me or our technical editors, Marty, NB1H, or Bob, WA1TKH. Let us know what types of articles you'd like to see more of and what you could do without. You can help us shape the magazine.

You say you want solid technical material and projects, projects, projects! Why not help us out? Write something up about that gizmo you just built and send it in. It's great to see your idea in print, and you get paid for your efforts!

Don't know how to put it on paper? Send for our Authors' Guide, which gives tips on how to write for *ham radio*. If you're going to Dayton, stop by our booth. Or catch me at the Writer's Forum; I'll be there and will be happy to answer any questions.

All of us are more than willing to work with you to make *ham radio* the finest Amateur magazine. Your ideas, suggestions, and articles are all welcome. Drop us a line or call and say hello. We're waiting to hear from you.

Terry Northup
Managing Editor



comments

remarks on television series

Dear HR:

There are several points in "the technology of television part 1: historical aspects," December 1987, which are inaccurate. The reference to 60 fields and 15.750 horizontal frequency is rounded and not precise. The reason for 60-Hz vertical rate is also not precise. The use of a satellite signal (network or otherwise) to establish frequency accuracy is not good engineering practice.

Sixty hertz (at the time cycles per second) was established because in the early days of black and white television it was a simple matter to line lock the vertical sweep oscillator to the ac mains. The human eye had become accustomed to the 60-Hz flicker; the 60-Hz flicker of the TV would be "in sync" with the light flicker and not be noticed. Interlace scanning was developed because the persistence of early phosphors was such that with non-interlace 30-Hz vertical rate the picture had a noticeable fade-out following the beam trace, much like a modern scope on slow sweep or early P7 SSTV monitors. To improve on this, the scan was changed to 60 Hz and the vertical scanning was interlaced to minimize the effect of phosphor persistence fading.

The current NTSC scanning rates are not 60/15750 but 59.95 and 15,734. When color was introduced it was desirable that the color system be compatible with existing black and white receivers. As developed, the color sub carrier is a multiple of the horizontal rate so that the sidebands interleve in the rf spectrum. The small adjustment in scanning rates from 60 to 59.94 and from 15,750 to 15,734 was done in order to provide close compatibility between color and black and white signals, so that the TV sets would still work without adjustment. England had more difficulties because they went from a 405 line B&W signal to a 625 line color signal. Intermediate sets had large switching systems to go between the different scanning rates. Fortunately, the 405 line system was largely on VHF channels and the new color system was on UHF channels.

The use of a satellite signal as frequency is not good practice. It is better to use a good stable sync generator. Modern units can remain accurate to within one cycle per month at the color carrier frequency of 3.579545 MHz. A cesium or rhubidium standard was used at the network level mainly because of reliance on very early vintage sync generators which did not have this inherent stability. Current network standards allow the use of modern sync gens without atomic reference oscillators. The satellite signal is not rock stable. There are doppler shifts caused by the routine firing of stability jets which keep the satellite stable (or fixed) at a particular orbital parking spot. However, there is always some wandering because of the gravitational influences of the moon, sun, etc., which prevent the "geo-stationary" satellite from being perfectly stable. If the source switches are non-synchronous, so is your gen-lock. Few network stations would take the chance of having a sync-gen relock during a local program, commercial, or news, so this practice is not encouraged. The networks do not make 100 percent in-sync switches and do not feel obliged to do so.

As an engineer with 22 years experience in broadcasting I found these and similar errors throughout the article. While as an ATVer I am gratified that any magazine is willing to devote some space to television technology, I would have preferred that it had been edited by a person who was also familiar with the subject so that these errors would have been found, since articles are used as reference in conversations, QSOs, etc.

I have found your magazine to be excellent in technical matters but this is one area where there should have been some reference checks.

Henry B. Ruh, KB9FO
former editor A5 Magazine.

battery storage

Dear HR:

I wish to comment on "A Battery-backed Master Power System," which appeared in your January 1988 issue.

The statement advising "...don't place the battery on a cement surface; the calcium in the floor will cause the battery to die!" is utter nonsense!

The facts are that the battery doesn't care where it's placed, but a shallow plastic pan placed under the battery is nice in case of acid spills! A new automotive battery has been sitting on my garage floor (without a pan) for over a year, and is still very much alive. A timer allows a trickle charge of about 75 mA for four hours daily. Such a system seems able to maintain a typical battery in "suspended animation" for a very long time. A duration of eight years has been verified with the test battery showing no measurable degradation.

Batteries placed on concrete floors and allowed to stand idle (no charging) have been monitored for long periods of time using continuous chart recorders. The degradation is identical with batteries placed anywhere else — slow self-discharge, depending on previous battery history and storage temperature. Some sulphation should be expected in about six months.

R.E. Elmore, W5JHJ
South Tulsa, Oklahoma 74145

the W8JK antenna
for 40, 30 and 20 meters

Face lift for an old friend using unconventional construction and feeding techniques

Here's a 40/30/20-meter antenna for both the experimenter who likes to tinker with unusual wire antennas and the seasoned Amateur looking for low-band operation equivalent to a three-element Yagi at elevations below one-half wavelength. Its odd appearance has raised quite a few eyebrows at my location. Performance has been more than satisfactory and it was pure fun to build.

The W8JK is a close-spaced array, constructed as two coplanar dipoles less than one-quarter wavelength apart and driven (usually) 180 degrees out of phase. It can be configured as a two-element array with each dipole approximately one-half wavelength long, or as a four-element array with each dipole approximately one wavelength long as in **fig. 1**. By making each dipole approximately one-half wavelength long on 40 meters with one-eighth wavelength spacing, the system operates as a two-element array on 40 meters with around 4.2 dB gain, and as a four-element array on 20 meters with about 5.7 dB gain. Spacing and phase difference cause the fields of the two elements to be subtractive and cancel in all directions except along the array axis. In this direction they produce the well-known figure-eight pattern. For a detailed discussion of close-spaced beams like the W8JK, see reference 1. The theory has already been well developed; this article is aimed at the practical details of construction and feeding.

dimensional considerations

Figure 2 shows how I built my version of the W8JK. A dipole length of 59 feet and spacing of 16 feet were chosen for operation on 40 and 20 meters. These dimensions were a compromise between construction considerations (a 90-foot distance between my two pine tree end supports) and theoretically recommended element lengths. Actually, any length between 1.25 wavelengths and slightly less than one-half wavelength will work without significantly affecting the characteristics of this antenna. This gives a dimensional range between 83 feet, 1.25 wavelengths on 20 meters, and 66 feet, one-half wavelength on 40 meters. There is no advantage in cutting element lengths for resonance in the 40-meter band because the VSWR remains very high, and tuned feeders and/or a tuning network will be required in either case. All feedline lengths and resonant frequencies discussed in this article are based on 59-foot antenna element lengths. Changing element lengths changes the feedline lengths required, but the same principles apply.

I recommend using 12-foot bridle arms with the bridles spaced close to the antenna supports as shown in **fig. 2**. Adjust the element lengths within the above limits. These adjustments don't affect operation or match, since this antenna is operated as a nonresonant one and uses tuned feeder lengths — this will make the impedance at the feeder input purely resistive. If length A in **fig. 2** is excessive, midpoint sag will quickly increase (unless tension is increased), and antenna height will decrease. If the bridle arms are significantly less than 12 feet, the bending moment on the 2 by 4 inch bridle supports will increase dramatically, causing them to break under the necessary 100-pound tension. Unacceptable antenna droop occurs with less than 100 pounds of tension. There is considerable interaction between the tension, bridle arm length, midpoint sag and loads on the bridle support. Keep this in mind if you must adjust the dimensions to accommodate your supports. If you use the dimensions shown in **fig. 2** and 100-pound counterweights, midpoint sag will be about 6 feet.

construction

Antenna construction is complicated, as compared with a dipole or Vee, by the need to feed both elements 180 degrees out of phase. Keep the elements relatively coplanar and maintain spacing between the wires. Do this by using bridles at each end of the antenna and a lightweight support at the midpoint.

The end bridle assemblies are made of lightweight fir or pine two-by-fours 16 feet long. I first tried making a truss assembly with PVC, but the design required to give it rigidity became complicated and the weight soon exceeded that of a simple wooden member.

By Ralph Fowler, N6YC, Route 1, Box 253R, Pearl River, Louisiana 70452

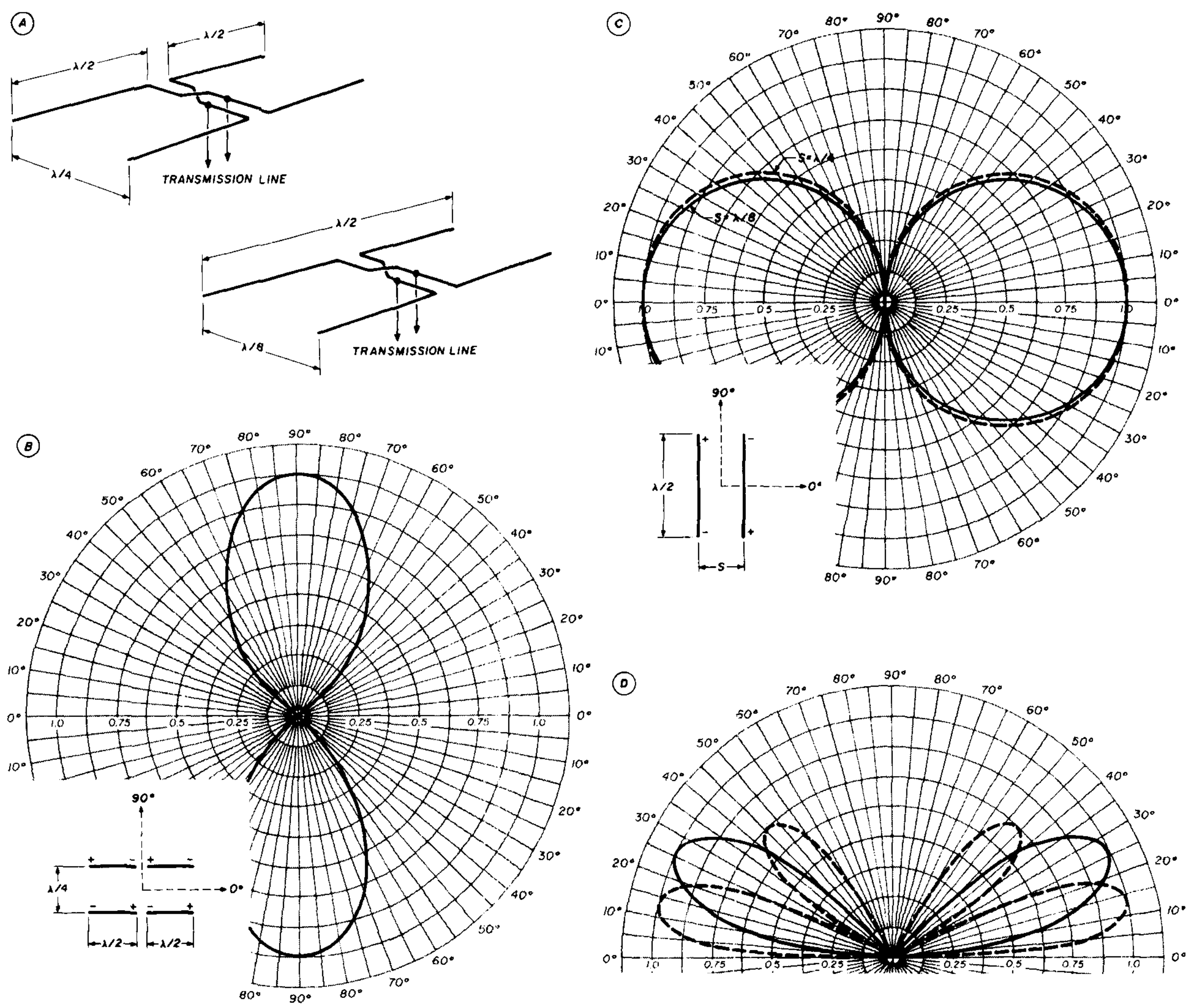


fig. 1. Two- and four-element W8JK. (A) Shows two- and four-element arrays, (B) is a free space directive diagram of a four-element array, (C) is a free space directive diagram of a two-element array, (D) is the vertical pattern of a two- and four-element array. Solid curve, height 1/2 wavelength; broken curve, height 1 wavelength.

Choose your lumber carefully and pick a lightweight, knot-free, sap-free piece. (You'd be surprised how the weight varies.) Weatherproof by applying two coats of spar varnish. Drill 1/4-inch holes near the ends to route the 1/4-inch polypropylene rope. Poly rope really isn't the best because it eventually deteriorates when exposed to sunlight. I have had good luck with mine over the past 14 months, but a better choice is the antenna rope advertised in ham magazines.

The center support is made of thinwall 2-1/2 inch PVC pipe as shown in **fig. 2**. It supports the phasing lines and maintains element spacing. Keep the wide spacing of the phasing lines; it serves a useful function. My Smith chart analysis of the phase line impedance transfer shows that the higher the impedance of this portion of the feedline (it is part of the feedline system), the closer the transferred impedance at the input end of the feedline will be to 50 ohms on 20 meters.

Use poly rope to truss the center support assembly and keep it from bending. The phasing lines are made from No. 12 wire; they pass through wire ties which attach to 2-inch ceramic standoffs. (You can use Plexiglas™ here but PVC is not recommended.) I attached the 450-ohm ladder line to the PVC with tape; this hasn't been a problem at 100 watts output. With higher power, especially on 20 meters, the high feedpoint resistance and VSWR create high rf voltages, so it may be necessary to use good quality standoffs here. PVC does not tolerate high rf voltages very well.

Because the end supports and antenna will sway in the wind, you must allow for some movement.

Attach 100-pound counterweights to the ends with a pulley arrangement (see **fig.2**). I believe that two weights are better than one; in high winds the range of motion is divided equally between the two counterweights, and the resultant peak tension presented to the wires and end insulators is decreased.

Antenna insulators are lightweight 2-1/2 by 12-inch pieces of 1/2-inch thick Plexiglas, with 1/4-inch holes carefully drilled and chamfered to minimize point loading, stress cracking, and failure.

Pulleys should be the best you can afford and are, in my opinion, the weakest part of the system. Those used in marine applications, though expensive, are probably the best. I chose the common metal hardware store variety, approximately 4 by 3 inches, for $6 each. So far they haven't failed even though the antenna has been subjected to the sway of tall pines in 60-mph winds.

I used No. 12 gauge stranded Copperweld™ (don't use ordinary softdrawn wire as it will stretch) for the elements. You must use a large-gauge wire because the antenna currents are relatively high as a consequence of the low radiation resistance. Losses in the wire can become considerable with small-gauge wire. The efficiency of my antenna with respect to copper losses is about 90 percent.

feeding the antenna

Before discussing antenna impedances, it is important to distinguish between the array feedpoint impedance (defined at the point where the 450-ohm ladder line connects to the phasing line) and the terminal impedance (at the ends of the elements where the phasing lines connect). Feedline input impedance is just that — the impedance at the transmitter end of the feedline.

This antenna's feedpoint impedance is low when operated at its fundamental half-wavelength frequency. At 7.15 MHz, I calculated approximately 11 + j13 ohms based on calculator rotation of measurements made at the input of the feedline. It is higher at 14.15 MHz (the higher 1.25-wavelength frequency range) — about 106 − j578 ohms according to similar calculations. Because neither value will match common feedline impedances, a high VSWR will exist and open-wire feeder, such as 450-ohm ladder line, is suggested (despite its reputation as a "fair weather feedline") to minimize VSWR losses. Although other types of balanced feedline can be used, 450-ohm ladder line handles a kilowatt and has the benefit of having a Z_0 that is useful as an impedance transformer on 20 meters.

For those who choose other feedlines, **fig. 3** shows an approximate Smith chart representation (chart Z_0 is 385 ohms) of the impedance of this antenna (with 59-foot elements) at the antenna feedpoint (points B

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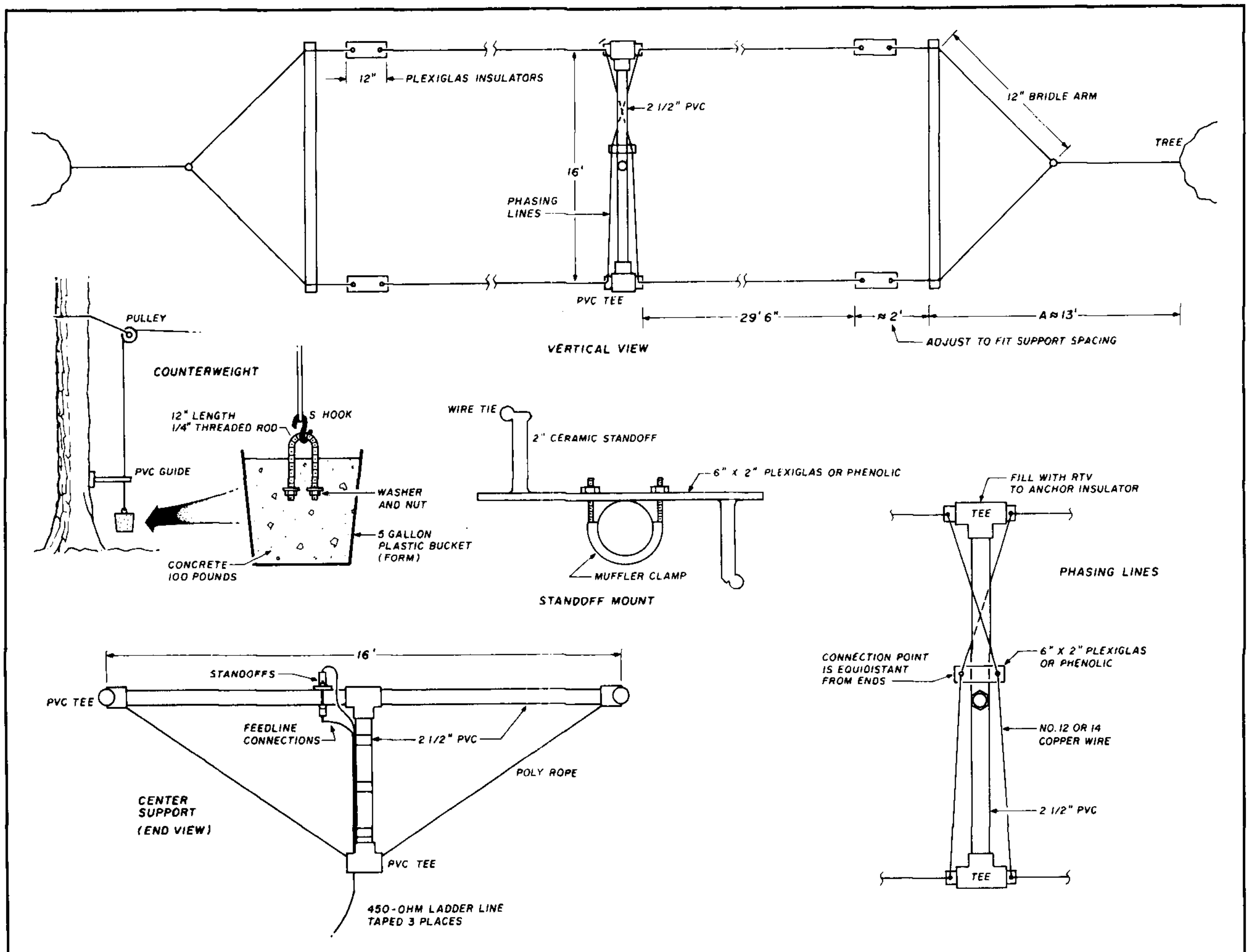

fig. 2. W8JK construction.

and C on the chart). The chart was constructed with data gathered with my collection of homebrew test equipment and "calculator rotated" to get at the feedpoint impedance. As such, it is approximate and useful as a guide for feedline length determination. These impedances can also be transformed on the **fig. 3** Smith chart or calculator rotated back along the 8.2 feet of phasing lines to the antenna terminals themselves. Using $V_f = 0.97$ and $Z_0 = 400$ ohms (estimated values) for the phasing line, antenna impedance turns out to be approximately 11 ohms at 7.93 MHz* and approximately 5000 ohms at 15.86 MHz, the dipole resonant frequencies. These terminal impedance values appear to be within experimental tolerances of the theoretical values. They are approximate due to the difficulty in

*The calculated radiation resistance of the array, approximately 11 ohms, is significantly higher than the theoretical value, near 4 ohms. This is likely because of the higher radiation resistance of the dipoles (estimated near 90 ohms), which are only 0.3 wavelengths above ground at 7.93 MHz. In any case, the increased resistance is beneficial. Residual reactance at 7.93 MHz, the dipole resonant frequency, is probably a result of slight mistuning between the elements and mutual reactance.

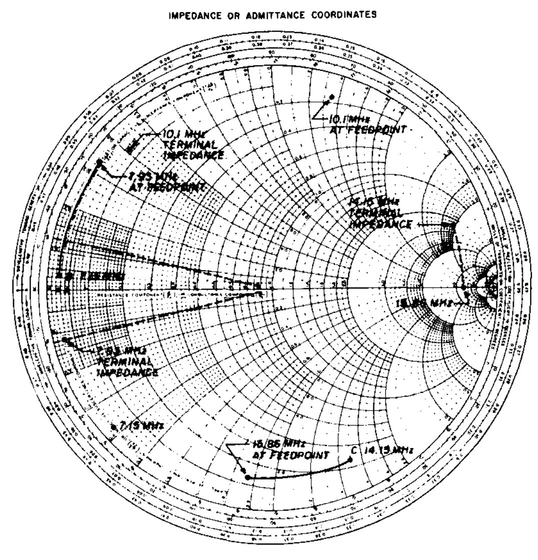

fig. 3. Feedpoint and terminal impedances of W8JK. Z_0 = 385 ohms.

fig. 4. BASIC listing of program for impedance "rotation" calculations.

```
10 REM THIS PROGRAM CONVERTS IMPEDANCES, R(P)/C(P) TO/FROM R(S)+jX(S),
   TRANSFORMS
20 REM THEM ALONG A TRANSMISSION LINE TO THE ANTENNA OR GENERATOR,
   AND COMPUTES
30 REM SWR, RETURN LOSS AND REFLECTION COEFFICIENT.
40 REM
50 PRINT CHR$(147):PRINT:PRINT
60 PRINT "1. CONVERT R(P)/C(P) TO R(S)+jX(S)":PRINT
70 PRINT "2. CONVERT R(S)+jX(S) TO R(P)/C(P)":PRINT
80 PRINT "3. COMPUTE SWR, RETURN LOSS AND REF. COEFF.":PRINT
90 PRINT "4. TRANSFORM R(S)+jX(S) TO ANTENNA":PRINT
100 PRINT "5. TRANSFORM R(S)+jX(S) TO GENERATOR":PRINT:PRINT:PRINT
110 INPUT"CHOOSE OPTION....";OPT
120 PRINT CHR$(147):OPT$=""
130 ON OPT GOTO 180,390,580,780,1050
140 GOTO 50
150 REM
160 REM
170 REM
180 REM THIS ROUTINE CONVERTS R(P)/C(P) FROM A PARALLEL TYPE NOISE BRIDGE
190 REM TO Z=R(S)+JX(S). ENTER CAP. VALUES AS "-", IND. VALUES AS "+".
200 REM
210 PRINT CHR$(147)
220 INPUT"INPUT R(P)";RP
230 INPUT"INPUT C(P) IN PF (CAP NEGATIVE)";CP
240 INPUT"INPUT FREQ IN MHZ";FR:FM=FR*1E+06
250 XP=1/(2*π*FM*CP*1E-12)
260 RS=RP/(1+(RP/XP)©2)
270 XS=RS*RP/XP
280 XS=(INT(100*XS))/100:RS=(INT(RS*100))/100
290 INPUT"EXTENDER USED ?";OPT$
300 IF OPT$="Y" THEN RS=RS-100
310 PRINT:PRINT:PRINT
320 IF XS>=0 THEN PRINT "Z=";RS;"+J";XS
330 IF XS<0 THEN PRINT "Z=";RS;"-J";-XS
340 PRINT:PRINT:OPT$=""
350 PRINT"PRESS 'RETURN' TO RESTART -"
360 INPUT"ANY OTHER KEY TO REPEAT";OPT$
370 IF OPT$="" THEN PRINT CHR$(147):GOTO 50
380 GOTO 180
390 REM
400 REM THIS ROUTINE CONVERTS Z=R(S)+JX(S) TO R(P)/C(P)
410 REM
420 PRINT CHR$(147)
430 INPUT"INPUT R(S)";RS
440 INPUT"INPUT X(S)";XS
450 INPUT"INPUT FREQ (MHZ)";FR:FM=FR*1E+06
460 RP=(RS©2+XS©2)/RS:XP=(RS©2+XS©2)/XS:CP=1E+12/(2*π*FM*XP)
470 RP=(INT(100*RP))/100:CP=(INT(100*CP))/100:PRINT:PRINT:PRINT
480 IF CP>=0 GOTO 500
490 PRINT"R(P)=";RP;"OHMS","C(P)=";CP;"PF (CAP)":PRINT:PRINT:GOTO 510
500 PRINT"R(P)=";RP;"OHMS","C(P)=";CP;"PF (IND)":PRINT:PRINT
510 OPT$=""
520 PRINT"PRESS 'RETURN' TO RESTART -"
530 INPUT"ANY OTHER KEY TO REPEAT";OPT$
540 IF OPT$="" THEN PRINT CHR$(147):GOTO 50
550 PRINT CHR$(147):GOTO 390
560 REM
570 REM
580 REM THIS ROUTINE CALCULATES SWR, REF. COEFF. AND RETURN LOSS
590 REM
600 PRINT CHR$(147)
610 INPUT"INPUT ZO OF LINE";ZO
620 INPUT"INPUT R(S)";RS
```

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```
630 INPUT"INPUT X(S)";XS
640 RO=SQR(((RS-ZO)©2+XS©2)/((RS+ZO)©2+XS©2))
650 RL=-20*LOG(RO)/LOG(10):SWR=(1+RO)/(1-RO)
660 RO=(INT(100*RO))/100:RL=(INT(100*RL))/100:SWR=(INT(100*SWR))/100
670 PRINT:PRINT:PRINT:OPT$=""
680 PRINT"REF. COEFF =";RO:PRINT
690 PRINT"RETURN LOSS =";RL;"dB":PRINT
700 PRINT"SWR =";SWR
710 PRINT:PRINT
720 PRINT"PRESS 'RETURN' TO RESTART -"
730 INPUT"ANY OTHER KEY TO REPEAT";OPT$
740 IF OPT$="" THEN PRINT CHR$(147):GOTO 50
750 PRINT CHR$(147):GOTO 580
760 REM
770 REM
780 REM THIS ROUTINE TRANSLATES R(S)+jX(S) TO THE ANTENNA (LOAD)
790 REM
800 PRINT CHR$(147)
810 INPUT"INPUT R(S)";RS
820 INPUT"INPUT X(S)";XS
830 INPUT"INPUT ZO";ZO
840 INPUT"INPUT LINE LENGTH (FT)";FT
850 INPUT"INPUT FREQ (MHZ)";FR:FM=FR*1E+06
860 INPUT"INPUT V(F) OF LINE (.XX)";VF
870 INPUT"INPUT LINE LOSS IN dB/100 FT.";DB:A=DB*FT/(100*8.686)
880 HW=.5*984*VF/FR: B=FT*π/HW
890 D=EXP(4*A)+1+2*EXP(2*A)*COS(2*B)
900 RB=(EXP(4*A)-1)/D:XB=(2*EXP(2*A)*SIN(2*B))/D
910 ALPHA=RS-RB*ZO:BETA=XS-ZO*XB:GAMMA=ZO-RS*RB+XS*XB:DELTA=RB*XS+RS*XB
920 RL=(ALPHA*GAMMA-BETA*DELTA)*ZO/(GAMMA©2+DELTA©2)
930 XL=(GAMMA*BETA+ALPHA*DELTA)*ZO/(GAMMA©2+DELTA©2)
940 PRINT:PRINT:PRINT:OPT$=""
950 RL=(INT(100*RL))/100:XL=(INT(100*XL))/100
960 IF XL>=0 THEN PRINT"Z(ANT)=";RL;"+J";XL:GOTO 980
970 IF XL<0 THEN PRINT "Z(ANT)=";RL;"-J";-XL
980 PRINT:PRINT
990 PRINT"PRESS 'RETURN' TO RESTART -"
1000 INPUT"ANY OTHER KEY TO REPEAT";OPT$
1010 IF OPT$="" THEN PRINT CHR$(147):GOTO 50
1020 PRINT CHR$(147):GOTO 780
1030 REM
1040 REM
1050 REM THIS ROUTINE TRANSLATES R(S) +JX(S) TO THE GENERATOR (SOURCE)
1060 REM
1070 REM
1080 PRINT CHR$(147)
1090 INPUT"INPUT R(S)";RS
1100 INPUT"INPUT X(S)";XS
1110 INPUT"INPUT ZO";ZO
1120 INPUT"INPUT LINE LENGTH (FT)";FT
1130 INPUT"INPUT FREQ (MHZ)";FR:FM=FR*1E+06
1140 INPUT"INPUT V(F) OF LINE (.XX)";VF
1150 INPUT"INPUT LINE LOSS IN DB/100 FT.";DB:A=DB*FT/(100*8.686)
1160 HW=.5*984*VF/FR:B=FT*π/HW
1170 D=EXP(4*A)+1+2*EXP(2*A)*COS(2*B)
1180 RB=(EXP(4*A)-1)/D:XB=(2*EXP(2*A)*SIN(2*B))/D
1190 ALPHA=RS+RB*ZO:BETA=XS+ZO*XB:GAMMA=ZO+RS*RB-XS*XB:DELTA=RB*XS+RS*XB
1200 RG=(ALPHA*GAMMA+BETA*DELTA)*ZO/(GAMMA©2+DELTA©2)
1210 XG=(GAMMA*BETA-ALPHA*DELTA)*ZO/(GAMMA©2+DELTA©2)
1220 RG=(INT(RG*100))/100:XG=(INT(100*XG))/100
1230 PRINT:PRINT:PRINT
1240 IF XG>=0 THEN PRINT"Z(GEN)=";RG;"+J";XG:GOTO 1260
1250 IF XG<0 THEN PRINT"Z(GEN)=";RG;"-J";-XG
1260 PRINT:PRINT:OPT$=""
1270 PRINT"PRESS 'RETURN' TO RESTART -"
1280 INPUT"ANY OTHER KEY TO REPEAT";OPT$
1290 IF OPT$="" THEN PRINT CHR$(147):GOTO 50
1300 PRINT CHR$(147):GOTO 1050
1310 END
```

THIS PROGRAM WAS WRITTEN IN C-64 BASIC. NOTE, HOWEVER, THAT "©" IN THE LISTING MEANS "EXPONENTIATION", i.e. 5©2=25.

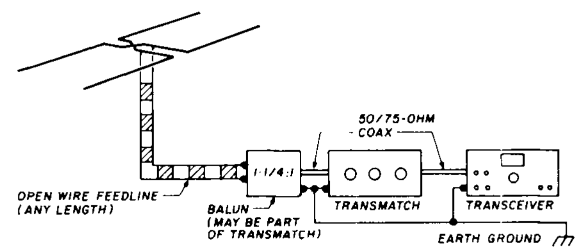

fig. 5. Matching the transmitter with a transmatch and balun.

possibility because this system presents impedances to the transmatch as high as 20,000 ohms and as low as 12 ohms, using 450-ohm feedline. Some transmatches won't match to these extreme impedances, and a ferrite balun may self-destruct with high power. One solution is to change the feedline; lengthening or shortening it by less than one-quarter wavelength should do the trick. Lengths to avoid are those approximating L = 30 + 60N feet at 7.15 MHz and 25 + 30N feet at 14.15 MHz. These will create very high impedances at the transmitter end of the feedline, are difficult to match, and bring high rf voltages into the station.

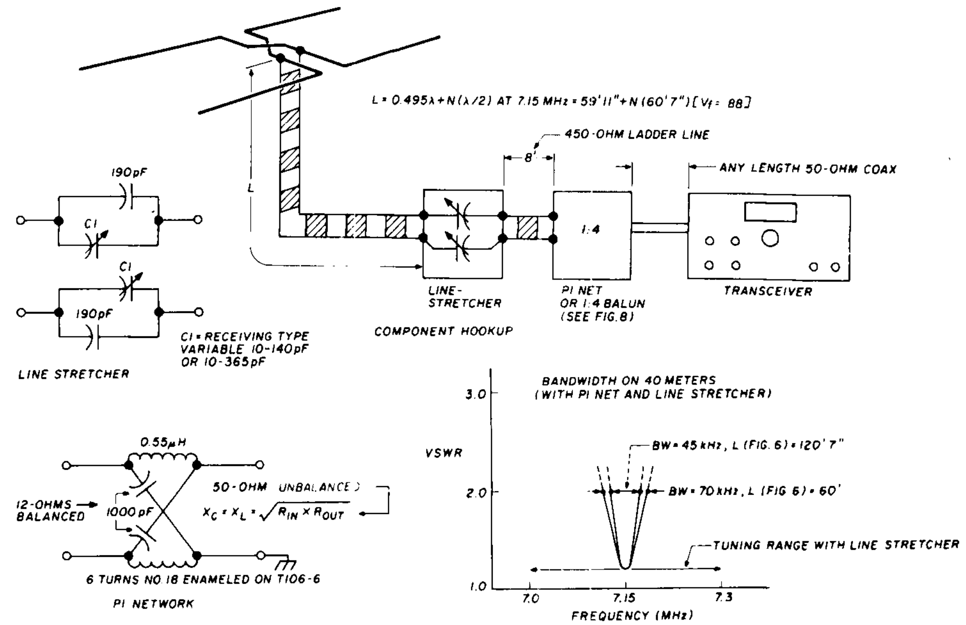

fig. 6. 40-meter configuration.

establishing a Z_0 for the phasing lines, which cross and therefore do not maintain constant separation and Z_0.

Figure 4 gives a BASIC listing of a simple program for impedance "rotation" calculations along a feedline and also calculation of VSWR, reflection coefficient, and return loss. The program accounts for losses in the line, a small but important contribution with open-wire line at 14 MHz and above.

Figure 5 shows how to match the feedline to the transmitter with a transmatch and balun. This allows unrestricted operation over the entire 20- and 40-meter bands (and anything in between). It also gives the most flexibility because you don't have to use a specified feeder length. The exception is when the feedline length you select presents an extremely high or low impedance at the input to the feedline — one which the transmatch can't handle. This is a definite

operating on 40 meters without a transmatch

This antenna can be considered a multiband antenna in that it radiates effectively on 40 and 20 meters, but the impedances on each band are very different. Without a transmatch, it requires tuned feedlines and/or matching networks, or some other impedance transformation scheme to get near 50 ohms. I took a simple approach and chose a feedline length that transformed the antenna feedpoint impedance to a low-value resistive impedance, then used a suitable network to get near 50 ohms. Since each band requires a different length of tuned feedline, a simple arrangement designed to switch a section of feedline and its associated matching network in or out from 40 to 20 meters would be effective. Because the inherent bandwidth of this antenna is rather restrictive on 40 meters (45 to 70 kHz at VSWR = 2), full-band operation over 7.0 to 7.3 MHz can be provided by adding a simple capacitive tuner. While the bother of changing feedline lengths when changing bands, and the narrow bandwidth on 40 may be somewhat objectionable, remember that it's hard to beat more than 4 dB gain at 7 MHz — unless you can afford the cost of three full elements and the monster tower to support it!

On 40 meters, if we feed this antenna with an integral number of half wavelengths of feedline, the impedance at the feedline input will be that at the antenna itself (approximately 12 ohms resistive at the resonant frequency). However, off resonance at 7 MHz, this antenna is capacitive (too short). But if we use the proper length feeder, we can compensate for the capacitive reactance and resonate the feeder/antenna system at 7.15 MHz. The impedance at the input to the feedline will remain near 12 ohms resistive. It's then a relatively simple matter to transform the 12 ohms close to 50 ohms with a 1:4 balun or balanced pi network. The only problem remaining is to overcome the relatively narrow bandwidth on 40 meters due to the low radiation resistance.

Figure. 6 shows the addition of a simple series capacitive tuner. I call it a line stretcher because it adds or subtracts series capacitance to each leg of the feedline, and effectively varies the feedline length by a small amount to maintain resonance (zero reactance) and allow operation over 7.0 to 7.3 MHz. Capacitors used in the line stretcher should be heavy enough to handle the current at the low-impedance level. I recommend transmitting micas or doorknobs for high power levels. Receiving-type micas, paralleled for added current capacity, should be sufficient at low (< 100 watts) power levels. Voltages are low so receiving-type variables can be used, and C_{max} can be anything in the neighborhood of 150 to 365 pF or more for an adequate tuning range. The range is essentially defined by the 190-pF capacitors. You should stay reasonably close to this value to avoid an excessively wide or narrow tuning range.

To use the line stretcher, find the length of main feedline required to make the antenna/feedline/line stretcher/pi network (or balun) combination present a near 50-ohm resistive input impedance at 7.15 MHz. Make sure that the length of feedline used to interconnect the pi network (or balun) to the line stretcher is the length that will be used in operation because it also affects the feedline input impedance. A line stretcher to pi net/balun interconnect length besides those recommended in **figs. 6** and **7** will work (assuming you prune the main feedline to accommodate them), but the tuning range will probably decrease and the VSWR will increase somewhat. The recommended lengths produce the best results.

Prune the main feedline length for lowest VSWR at the center of the band, 7.15 MHz, with the capacitor plates of the line stretcher half meshed. This should allow operation over 7.0 to 7.3 MHz, with the line stretcher capacitors adjusted equally to maintain balance. Simplify main feedline pruning by using a noise bridge connected to the transmitter side of the pi net or a VSWR meter. In the absence of these, the lengths recommended in the text will get you close, assuming you duplicate my design.

Whether you choose to use a 1:4 coax balun (balanced to unbalanced) shown in **fig. 8** or the balanced pi network shown in **fig. 6** is a matter of taste, since both perform well. The pi net is a balanced adaptation of the traditional pi network used in virtually all transmitters. Component values are dictated by the frequency of operation and transformation values. They are defined by:

$$X_l = X_c = \sqrt{R_l \cdot R_2} \qquad \textbf{(1)}$$

where R_1 is 12 ohms (40 meters) and R_2 is Z_0 of the transmitter, generally 50 ohms. Capacitance values are close to 900 pF and inductance near 0.55 μH for a 12- to 50-ohm conversion at 7.15 MHz.

As a test, I built the pi net using small postage-stamp size 1000-pF 300-volt silver micas and T106-6 toroids. With 100 watts output from my TS-830S there were barely perceptible signs of capacitors heating while operating under matched-load conditions. However, this was only an experiment. To avoid possible failure under accidental mismatch conditions, transmitting doorknob or mica types are recommended. Bandwidth of the pi net is shown in **fig. 8** along with the bandwidth of a 1:4 coax balun for comparison. My measurements indicate that the pi net built as shown will transform resistive impedances between 6 and 14 ohms with VSWR less than 1.7 at 7 MHz. Phase imbalance caused by component tolerances was not evaluated but probably is no worse than that of a balun. If you choose to build the coax balun instead of the pi net, RG-58/U should be suitable for a kilowatt. **Figure 8** shows details of this unconventional coax balun.

A 1:4 ferrite balun design isn't shown but should perform equally well if attention is given to the design of the balun windings. Remember: to transform 12 ohms to 48 ohms, it's important that the Z_0 of the balun windings be the square root of quantity $12 \times 48 = 24$ ohms to avoid introducing reactances, thereby reducing the already narrow bandwidth. A low Z_0 requires large-gauge (No. 14 or larger) wire, preferably bifilar wound. And unless you can find a 1:4 balanced-to-unbalanced design (I couldn't), you will have to use two baluns back to back, perhaps a 1:4 balanced-to-balanced followed by a 1:1 balanced-to-unbalanced. These difficulties led me to opt for Dietrich's[2] 1:4 balanced-to-balanced coax balun as

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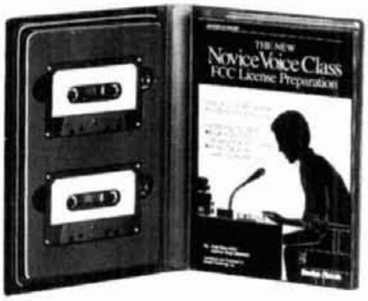

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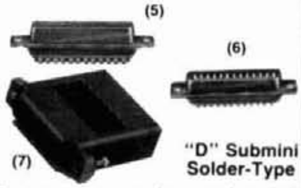

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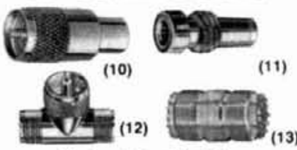

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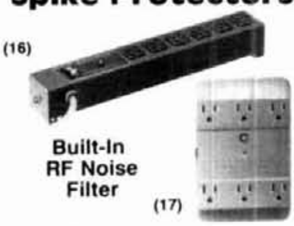

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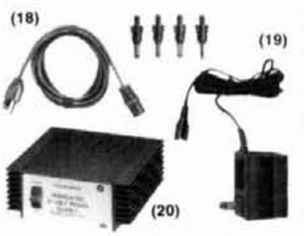

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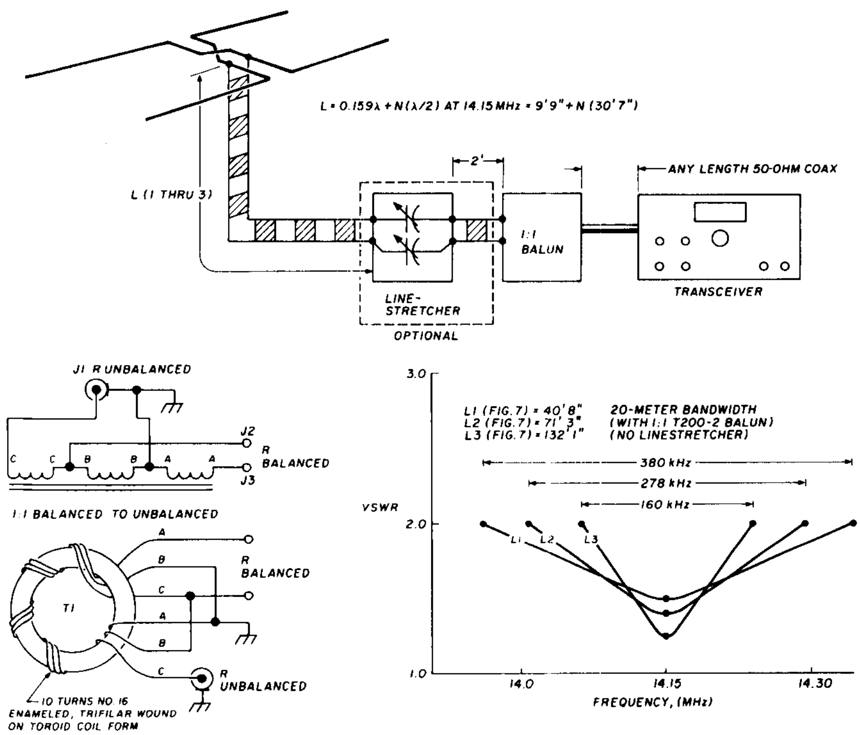

fig. 7. 20-meter configuration.

an alternate to the pi net. The main disadvantage of the coax balun is the bulk of the coax cable.

Determine feedline length from the Smith Chart shown in **fig. 3**. The wavelength is 0.495 at 7.15 MHz between point B clockwise to point A, where the feedpoint impedance is resistive. Substituting into

$L = (N \cdot 984 \cdot V_f)/F$

Where N = 0.495, V_f = 0.88, and F = 7.15 MHz gives the required length in feet. For example, 450-ohm ladder line with V_f = 0.88 requires a length of 60 feet. Any number of half wavelengths can be added to this to reach the transmitter without affecting the impedance at the line input (neglecting losses). Note that feedline length does affect operating bandwidth, as evidenced by the VSWR curves plotted for different feedline lengths in **figs. 6** and **7**.

The 8-foot length of line connecting the line stretcher to the pi net is negated by the capacitive reactance introduced by the line stretcher with the plates meshed halfway at 7.15 MHz. The effects of the two cancel each other. Increasing or decreasing capacitance, then, adds or subtracts feedline to maintain a resistive input impedance over the 7.0- to 7.3-MHz band. Line stretcher reactance range at 7 MHz is indicated by the pie-shaped region on the Smith chart of **fig. 3**.

If you calculate the proper length as shown above, 300-ohm TV line should be acceptable for low-power, single-band operation on 40 meters. However, if you operate on 20 meters, 450-ohm line should be used (unless you use a transmatch). The line, in this instance, acts as a transmision line and also an impedance-transforming line section to get the input impedance reasonably close to 50 ohms.

operating on 20 meters without a transmatch

Operating this antenna using tuned feeders without a transmatch (**fig. 7**) is much easier on 20 meters than on 40. The antenna's impedance transforms to near 34 ohms using the properties of 450-ohm ladder line. Bandwidth at the VSWR = 2 points is approximately 160 to 380 kHz, depending on feedline length. Use of the line stretcher is optional unless feedline length is excessive. Bandwidths for three feedline lengths are shown in **fig. 7**.

Line stretcher setup and use are similar to that for 40 meters, but approximately 2 feet are used to interconnect it and the 1:1 balun. Line stretcher tuning range at 14 MHz drops because of the decreased reactance of the line stretcher capacitors, so using smaller value fixed capacitors may help.

The 1:1 balun can be a coax or an air-core/toroidal design. An air-core or toroidal design in this application is relatively simple when compared to the design of the 12- to 48-ohm balun used on 40 meters. The required impedance of the windings is near 41 ohms.

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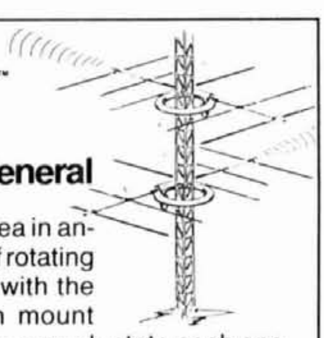

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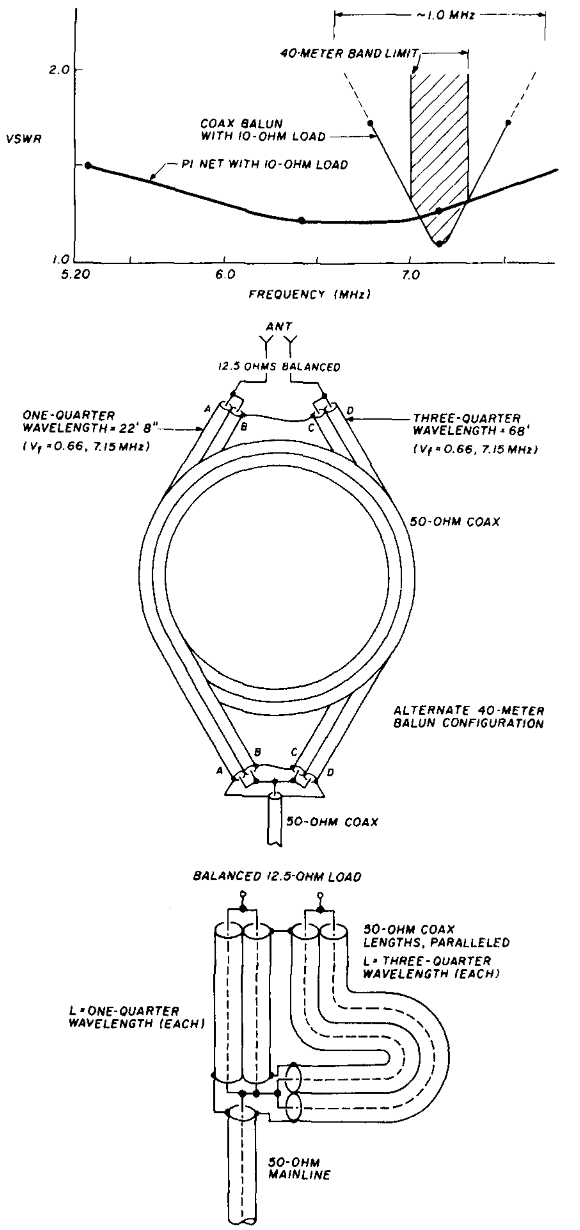

fig. 8. Bandwidth of the pi net and details of coax balun.

The balun can be easily made with ten turns, trifilar wound (this works best) of No. 16 gauge enameled wire, on an air or powered iron core. The core should be large enough to handle your anticipated running power. A T-200-2 core should handle up to a kilowatt when operating within the VSWR = 2 bandwidth. **Fig. 7** shows a toroid balun built along these guidelines.

On 20 meters, feedpoint impedance (point C on the Smith chart in **fig. 3**) is close to 106 − j578 ohms. You can use a 0.159 λ + N•(λ/2) length of 450-ohm feedline (measured Z_0 of 385 ohms) to transform this to approximately 34 ohms at the input end. See **fig. 7.** The length of feedline required is 9 feet 9 inches + (30 feet 7 inches)N, to operate at 14.15 MHz (V_f = 0.88).

Using 450-ohm feedline is important because, unlike a simple half wavelength of feedline, an arbitrary length of feedline will transform impedances as a function of line length and Z_0 of the line. For example, the 450-ohm ladder line I used had a measured Z_0 of approximately 385 ohms and $V_f = 0.88$ [see **ref. 3**]. The feedpoint impedance, point C on the **fig. 3** Smith chart, along a 0.159 wavelength section of feedline transforms to about 34 ohms. Using 300-ohm line as a transformer results in a transformed impedance of close to 23 ohms (VSWR = 2.2 at $Z_0 = 50$ ohms). This reduces the usable bandwidth somewhat as compared to 450 ohm line. Similarly, using 600-ohm open-wire line will result in a transformed impedance of approximately 58 ohms. Line with an actual Z_0 of 450 ohms transforms to approximately 42 ohms. Use these figures as a guide if you plan to try different feedlines. Remember that the above figures are based on an antenna with 59-foot elements spaced 16 feet apart and about 40 feet above average soil. Unless the phasing line section is closely duplicated, you will probably get slightly different resistive impedances at the feedline input and have to trim the feedline lengths. Don't let this discourage you — the pi net described in **fig. 6** is a neat and simple solution to the impedance transformation problem, once you measure the feedline input impedance with an rf or noise bridge.

operating on 30 meters

This antenna can also be operated on 30 meters by adjusting the length of the feedline. With 30 feet 2 inches + (42 feet 10 inches)N of feedline ($V_f = 0.88$), the input impedance will be approximately 23 ohms. A pi net constructed using information in **fig. 6** should give a good match and ample bandwidth. While I have not measured the radiation pattern, I would guess it's probably not a lot different from the 40- or 20-meter patterns.

Building and evaluating this rather unconventional antenna took me about a year. I hope the information here helps you better understand and build the W8JK. Any questions accompanied by an SASE are welcome.

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The original BASIC MINIMUF version, required only 4 to 6K of instruction and dynamic storage. The *QST* article that introduced MINIMUF concentrated on the genesis of its algorithms and ionospheric modeling and provided an elementary user guide.

initial goals

I wanted to and succeeded in improving MINIMUF's speed. Then two articles by Elwell made me think that a lot more could be done to build a truly useful program.[2,3] I had already merged MINIMUF into a gray-line program[4] and had been using a bearing/distance program.[5] **Figure 1** is a listing of a complete program that does it all.

PATHFINDER is longer than MINIMUF though not much faster. It is more powerful than the older version of MINIMUF as it uses the upgrade (MINIMUF-85) that models polar paths much more accurately, and takes into account many variable factors that the previous version (MINIMUF-3.5) did not.[6,7]

MINIMUF-85 is an empirically derived model that predicts near real time MUF, developed by the Naval Ocean System Center*.[8] After having developed my original program around MINIMUF-3.5 I was sure that its improvement in speed could be put to use more efficiently. I contacted Bob Rose, K6GKU, and, received a copy of MINIMUF-85. I was able to upgrade PATHFINDER to the new algorithm and verify it. The older programs have been in use for some time and have been documented. The Navy has tested and verified MINIMUF-85 and now recommends it for use in all applications currently using MINIMUF-3.5.

inside MINIMUF

The MINIMUF algorithms follow a well-established procedure for determining both the MUF and preferred operating frequency. This procedure:

- Describes the path of interest in terms of its control points (locations 2000 km from each end of the path).
- Plots these points on a transparent overlay that is placed on a map of the earth.
- Records the MUF at the control points by reading the map MUF contours.

Determine the path MUF for a particular time and day by referring to additional charts and making calculations. The maps are keyed to solar activity, angle of incidence, time of day and year. This manual method has been described in the Amateur literature.[9]

The key to MINIMUF is the model of the ionosphere, found in the last two dozen lines of the original program code. This algorithm implements the characteristics of the maps used in the manual method. All of the code in MINIMUF preceding this model defines the number and location of the control points and the

*The NOSC technical publications for MINIMUF-3.5 and MINIMUF-85 are available through NTIS; 5285 Port Royal Road, Springfield, Virginia 22161. See *ham radio*, July 1987, page 49.

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fig. 1. The PATHFINDER program.

```
10 PRINT "    Welcome to PATHFINDER-85"
20 PRINT "COPYRIGHT 1987 by Ronald C. Todd"
30 'MICROSOFT BASIC version, Release 1.10, 2/2/88
40 DIM M(12),WW(19),LL(19),K9(19),SR(19),SS(19)
50 DIM C0(19),T9(19),ZW(19),YX(19),YS(19),ZX(19)
60 DIM FF(19),LG(19),GF(19),G7(19),G8(19),ZZ(19),MOUT(36)
70 DEFINT I: M$="JanFebMarAprMayJunJulAugSepOctNovDec"
80 DATA 31,28,31,30,31,30,31,31,30,31,30,31
90 DATA -.06,-.037,.018,-.003,.025,.018
100 DATA .007,-.005,.006,.017,-.009,-.004
110 DATA 3.83,-22.915,-7.317,.51,.06,-.43,-9.471,-3.197
120 DATA -.082,-.156,-.391,-.106,0,0,-.242,-.15
130 DATA .011,.087,-.043,.003,-.013,-.022,.003,0,.005,0,0,.018
140 FOR I=1 TO 12: READ M(I): NEXT I: PI=3.14159: P0=PI/2
150 P1=2*PI: P2=2/PI: P5=PI/5: P6=SIN(PI/12): R0=PI/180
160 R1=180/PI: CC=-23.5*R0: LH=43.7876: WH=70.4348 'home
170 GOSUB 8000: GOSUB 8200: GOSUB 8400: GOSUB 8520: GOSUB 7200
200 INPUT "Opt: 1=Input 2=Anal 3=List 4=Quit ";IO
210 ON IO GOTO 220,240,280,9999: GOTO 200
220 INPUT "Opt: 0=Top 1=Date 2=Flux 3=SSN 4=Target 5=Home ";IO
230 ON IO GOSUB 8000,8200,8300,8400,8500: GOSUB 7200: GOTO 200
240 IL=0: S6=0: INPUT "Opt: 0=Top 1=B/D 2=Grey 3=MUF ";IO
250 ON IO GOSUB 1400,1300,260: GOTO 200
260 S6=P6: INPUT "Opt: 0=Top 1=Short 2=Long 3=Radial ";IO
270 ON IO GOSUB 1010,1000,1100: RETURN
280 IF IL=2 THEN I=18: IA=10 ELSE I=12: IA=100
290 LPRINT "GMT/DEG","MUF","GMT/DEG","MUF"
300 FOR IH=0 TO I-1: FOR IB=0 TO I STEP I
310 LPRINT (IH+IB)*IA,MOUT(IH+IB),
320 NEXT IB: LPRINT: NEXT IH: GOTO 200
1000 IL=1                                  'HOURLY MUF DRIVER
1010 GOSUB 8420: GOSUB 3000: GOSUB 4000: GOSUB 3100
1020 GOSUB 7100: PRINT "GMT","MUF","GMT","MUF"
1030 FOR IH=0 TO 11                  'SWEEP TIME
1040 FOR IB=0 TO 12 STEP 12: T5=IH+IB: GOSUB 2000
1050 PRINT T5*100,J9;"      ",;: MOUT(IH+IB)=J9
1060 NEXT IB: PRINT: NEXT IH: RETURN
1100 INPUT "What GMT hour for display";T5 'RAD MUF SETUP
1110 IL=2: IF (T5>=24 OR T5<0) THEN PRINT "ERROR": GOTO 1100
1120 PRINT "1 Hop = 2488 mi (4000 Km). Long Path beyond 5"
1130 INPUT "How many hops for display [0.1 to 9.9]";K1
1140 IF ABS(K1-5)>4.9 THEN PRINT "ERROR": GOTO 1130
1150 G1=K1*P5: GOSUB 4000: PRINT "DEG","MUF","DEG","MUF"
1160 FOR IH=0 TO 170 STEP 10                   'SWEEP BEARING
1170 FOR IB=0 TO 180 STEP 180: A0=IH+IB
1180 IF IH=0 THEN PB=(A0+.1)*R0 ELSE PB=A0*R0
1190 A=COS(PB): B=G1: GOSUB 3300: L2=L0: GOSUB 3100
1200 GOSUB 2000: PRINT A0,J9;"      ",;: MOUT(A0\10)=J9
1210 NEXT IB: PRINT: NEXT IH: RETURN
1300 W0=W1: L0=L1: GOSUB 5000: PRINT "At home QTH": GOSUB 7000
1310 GOSUB 8420: W0=W2: L0=L2: GOSUB 5000: PRINT "At targ QTH"
1320 GOSUB 7000: RETURN
1400 GOSUB 8420: GOSUB 3000: GOSUB 7100
1410 IL=1: GOSUB 3000: GOSUB 7100: RETURN
2000 J9=100: FOR I=1 TO IK                    'MUF SET UP
2010 SLT=T5-WW(I)*P2*6: IF SLT<0 THEN SLT=SLT+24
2020 IF SLT>=24 THEN SLT=SLT-24
2030 G0=0: SAD=1: IF C0(I)<=-P6 THEN 2300
2040 IF SS(I)<SR(I) THEN 2060                 'INVERTED DAY
2050 IF (T5-SR(I))*(SS(I)-T5)<0 THEN 2200 ELSE 2100
2060 IF (T5-SS(I))*(SR(I)-T5)>0 THEN 2200 ELSE 2100
2100 IF SR(I)>T5 THEN X=T5+24 ELSE X=T5             'DAY G0
2110 YM=PI*(X-SR(I))/K9(I): X=(SR(I)-X)/T9(I)
2120 GOSUB 6100: FM=X
2130 G0=(SIN(YM)+ZW(I)*(EXP(FM)-COS(YM)))*G8(I)
2140 SAD=1.11-.01*SLT: IF G0<G7(I) THEN G0=G7(I)
2150 GOTO 2300
2200 IF SS(I)>T5 THEN X=T5+24 ELSE X=T5           'DARK G0
2210 SAH=P1*(14*(X-SS(I))/(24.01-K9(I))+1)/15
2220 FM=(SS(I)-X)/2: SAD=1.0195: RESTORE 90
2230 FOR IA=1 TO 6: Y=IA*SAH: READ C1,C2
2240 SAD=SAD+C1*SIN(Y)+C2*COS(Y): NEXT IA
2250 G0=ZZ(I)*EXP(FM)
2300 G2=SQR(6+A1*SQR(G0))+GF(I)                       'RAW FoF2
2310 G2=G2*(1-.1*EXP((K9(I)-24)/3))               'LONG DAY ADJ
2320 G2=G2*(1+(1-SGN(L1)*SGN(L2))*.1)              'TRANS E ADJ
2330 G2=G2*(1-.1*(1+SGN(ABS(SIN(LL(I)))-COS(LL(I))))) 'HI LAT
2340 SAE=A2*A3*SAD: IF ABS(LG(I))<.95993 THEN 2600
2400 PHI=SLT*PI/12: V=SIN(Y1/2): IF LG(I)>0 THEN 2430  'POLAR
2410 X=EXP(-1.2*(COS(LG(I)+CC*COS(PHI))-COS(LG(I))))
2420 PLR=(2+.012*S9)*X*(1+.3*V): GOTO 2480
2430 U=COS(Y1): X=V*(.5*(YX(I)-ZX(I))-YX(I)^8)
2440 X=X-(1+V)*U*SGN(ZX(I))*SQR(ABS(ZX(I)))*EXP(-4*YX(I)^2)
```

```
2450 PLR=2.5+.02*S9+U*(.5+(1.3+.002*S9)*YS(I))
2460 PLR=PLR+(1.3+.005*S9)*COS(PHI-PI*(1+X))
2470 PLR=PLR*(1+.4*(1-V*V))*EXP(-V*YS(I))
2480 X=(1-FF(I))*G2*G2/8.12+.66*FF(I)*PLR
2490 IF X>=0 THEN G2=2.85*SQR(X)
2600 G2=G2*M9*SAE: IF G2<J9 THEN J9=G2             'FIN MUF
2610 NEXT I: IF J9<2 THEN J9=2 ELSE IF J9>50 THEN J9=50
2620 J9=INT(10*J9)/10: RETURN
3000 X=SIN(L1)*SIN(L2)+COS(L1)*COS(L2)*COS(W2-W1): GOSUB 6000
3010 G1=X: X=(SIN(L2)-SIN(L1)*COS(G1))/(COS(L1)*SIN(G1))
3020 GOSUB 6000: IF SIN(W2-W1)>0 THEN PB=P1-X ELSE PB=X
3030 IF IL=1 THEN PB=PB+PI: G1=P1-G1
3040 IF PB>P1 THEN PB=PB-P1
3050 A=COS(PB): RETURN
3100 FOR I=1 TO IK: GF(I)=0: B=I*L         'POINT DEF & PARAM
3110 IF G1<=.94174 THEN B=1/(2*K6)+(I-1)*(.9999-1/K6)
3120 B=B*G1: GOSUB 3300: GOSUB 3400: WW(I)=W0: LL(I)=L0
3130 SM=.9792*SIN(L0)+.2028*COS(L0)*COS(W0-1.2043): X=SM
3140 GOSUB 6000: LG(I)=P0-X: IF ABS(LG(I))<.95993 THEN 3210
3150 SM=SIN(LG(I)): GF(I)=.3789*SQR(1+3*SM^2)-.5: Y=COS(LG(I))
3160 X=2.2+(.2+.001*S9)*SM: X=(X*Y)^6: GOSUB 6100
3170 FF(I)=EXP(-X): IF LG(I)<0 THEN 3210
3180 X=COS(L0)*SIN(W0-1.2043)                      'GEOMAG LONG
3190 IF Y=0 THEN X=P0*SGN(X) ELSE X=X/Y: GOSUB 6000: X=P0-X
3200 YX(I)=SIN(X/2): YS(I)=(COS(X/2-PI/20))^4: ZX(I)=SIN(X)
3210 GOSUB 5000: NEXT I: RETURN
3300 C=P*COS(B)+Q*SIN(B)*A: X=C: GOSUB 6000: L0=P0-X: RETURN
3400 X=(COS(B)-COS(X)*P)/(Q*SIN(X)): GOSUB 6000
3410 IF SIN(PB)<0 THEN W0=W1+X ELSE W0=W1-X
3420 IF ABS(W0)>PI THEN W0=W0-P1*SGN(W0): GOTO 3420
3430 RETURN                                         'POINT LONG
4000 IF G1<=P5 THEN K6=1: M9=1 ELSE K6=G1/P5: M9=.5
4010 M9=2.5*G1*M9: IF M9>P0 THEN M9=1 ELSE M9=SIN(M9)
4020 M9=1+2.5*M9*SQR(M9): IK=INT(G1/.62784)+1: L=1/(2*IK)
4030 IF G1>.94174 THEN IK=2*IK-1
4040 RETURN
5000 C0(I)=COS(L0+Y2): C0A=ABS(C0(I))           'DAYLIGHT CHAR
5010 IF C0(I)<-S6 THEN K9(I)=0: GOTO 5110        'SUNR CHECK
5020 K8=6*(2+W0*P2)-ET                                'NOON
5030 IF K8<0 THEN K8=K8+24 ELSE IF K8>=24 THEN K8=K8-24
5040 X=(SIN(Y2)*SIN(L0)-S6)/(COS(Y2)*COS(L0)+.001)
5050 GOSUB 6000: X=6*X*P2: K9(I)=2*X                'LEN DAY
5060 SR(I)=K8-X: IF SR(I)<0 THEN SR(I)=SR(I)+24      'SUNR
5070 SS(I)=K8+X: IF SS(I)>=24 THEN SS(I)=SS(I)-24    'SUNS
5080 IF C0A<.62094 THEN T9(I)=.1 ELSE T9(I)=9.7*C0A^9.6
5090 X=K9(I)/T9(I): ZW(I)=PI/X: G8(I)=C0A/(1+ZW(I)^2): GOSUB 6100
5100 ZZ(I)=(EXP(-X)+1)*ZW(I)*G8(I): G7(I)=EXP((K9(I)-24)/2)*ZZ(I)
5110 RETURN
6000 IF ABS(X)>=1 THEN X=P0*SGN(X) ELSE X=ATN(X/SQR(1-X*X))
6010 X=P0-X: RETURN
6100 IF ABS(X)>87 THEN X=87*SGN(X)
6110 RETURN
7000 IF C0(I)<=0 THEN PRINT "Day not defined": GOTO 7050
7010 PRINT "Sunrise at:";INT(40*INT(SR(I))+60*SR(I))/100;"Z"
7020 PRINT "Sunset  at:";INT(40*INT(SS(I))+60*SS(I))/100;"Z"
7030 PRINT "Day length:";INT(40*INT(K9(I))+60*K9(I))/100;"HR.MIN"
7040 PRINT "Noon    at:";INT(40*INT(K8)+60*K8)/100;"Z"
7050 RETURN
7100 PRINT "Path length =";INT(G1*3959);"miles"
7110 PRINT "Path bearing at home QTH =";INT(PB*R1): RETURN
7200 PRINT "DATE: "MID$(M$,3*M0-2,3)" "D6
7210 PRINT "HOME AT LAT"LH"LONG"WH" TARGET AT LAT"LT"LONG"WT
7220 PRINT "SOLAR FLUX="SX" SUN SPOT NUMBER="S9: RETURN
8000 INPUT"Month number";M0: INPUT"Day of month";D6: Y1=D6
8010 FOR I=1 TO M0-1: Y1=Y1+M(I): NEXT I: Y1=Y1*P1/365
8020 Y2=.456: ET=.008: RESTORE 110
8030 FOR I=1 TO 4: X=I*Y1: READ C1,C2,C3,C4
8040 Y2=Y2+C1*SIN(X)+C2*COS(X): ET=ET+C3*SIN(X)+C4*COS(X): NEXT I
8050 Y2=-Y2*R0: ET=ET/60: KX=M0*PI/6: A3=.9925: RESTORE 130
8060 FOR I=1 TO 6: X=I*KX: READ C1,C2
8070 A3=A3+C1*SIN(X)+C2*COS(X): NEXT I: RETURN
8200 INPUT"Solar Flux [64 to 301]";SX
8210 S9=INT((-.728+SQR(.529984-(63.75-SX)*.00356))/.00178)
8220 A1=.814*S9+22.23: A2=1.3022-.00156*S9: RETURN
8300 INPUT"Sun Spot Number [0 to 250]";S9
8310 SX=63.75+.728*S9+.00089*S9*S9:GOTO 8220
8400 INPUT"Target Latitude [- south, 89.9 max]";LT
8410 INPUT"Target Longitude [- east]";WT
8420 L2=LT*R0: W2=WT*R0: RETURN
8500 INPUT"Home Latitude [- south, 89.9 max]";LH
8510 INPUT"Home Longitude [- east]";WH
8520 L1=LH*R0: W1=WH*R0: P=SIN(L1): Q=COS(L1): RETURN
9999 END
```

determination of the geometry of the solar illumination of these points at the time of analysis on the day selected.

The basis for the MINIMUF model is that MUF is a function of the product of the critical frequency of the ionosphere and a path-related M-factor. MINIMUF-3.5 uses fairly simple relationships to model these functions. MINIMUF-85 expands on these primary relationships, considers more control points on longer paths and takes into account the special conditions in polar regions.[10] MUFs are affected differently when control points fall within polar regions. MINIMUF-85 factors in sunspot number-related effects to the critical frequency and M-factor, adds seasonal and diurnal variation to the M-factor, and considers particle precipitation effects for control points in or near polar regions.

The MINIMUF-85 model reduces the RMS errors in MUF for polar paths from the older MINIMUF version of 10.92 MHz to 3.5 MHz, and improves the overall average bias in MUF predictions. The lack of correlation between solar flux and smoothed sunspot numbers can still amount to significant errors in the predicted MUF. It is recommended that you use average values of solar flux as the input variable because the F-layer of the ionosphere has a lot of inertia and does not easily respond to short-term changes in solar conditions.

There is considerable math and physics involved. Consequently, many users do not realize that MINIMUF depends heavily on the same routines and algorithms necessary to implement bearing/distance and gray-line analysis applications. MINIMUF can be made to report this information without requiring much additional code. Using these same routines, the MUF can be determined for radial presentation for any hour of the day and path length. MINIMUF can produce an application providing virtually all the information required by the average hf operator. Further, by accessing a world data file of latitudes and longitudes keyed to call prefixes, we could generate a product for all DXers.

basic program requirements

The first step in designing PATHFINDER was to define the tasks it would accomplish; below is a list of these primary features.

- HOURLY MUF PROJECTIONS SHORT PATH
- HOURLY MUF PROJECTIONS LONG PATH
- RADIAL MUF PROJECTIONS 250 TO 22500 MILES
- BEARING AND DISTANCE REPORT SHORT PATH
- BEARING AND DISTANCE REPORT LONG PATH
- PATH GRAY-LINE REPORT
- MINIMUM CODE SIZE
- MINIMUM RESPONSE TIME
- POSSIBLE HOOKS TO LAT/LONG DATA FILE

Next, I surveyed MINIMUF and several bearing/distance and gray-line programs for comparable features, algorithms, and routines.

The subsequent steps were easier once I had decided on the program requirements. Program flow and variable requirements were evaluated for all these sources *before* setting down a single line of pseudocode. I planned what I needed and how I would accomplish it with minimum overhead. The increased computational burden in PATHFINDER does not cause a major increase in total response time when compared to MINIMUF in identical applications. The reason for the significant improvement in performance while model sophistication and computation have grown by nearly 100 percent is a result of four basic concepts described next.

speed increase

First, MINIMUF spends a lot of time in its loops recalculating variables which, once they are determined, do not change. All computations not absolutely necessary to repeat have been moved out of the loops, precalculated, and placed in arrays. Computation time is saved with only a minimal increase in storage requirements. The general purpose procedures are now subroutines supporting the other applications of the program. Second, where prudent, the use of the division operation, has been minimized particularly in repeated sequences. Third, where possible, control statements have been restructured to function on integer and simple variables rather than real variable types and compound functions. Finally, multiple program statements have been placed on a single logical line which helps most BASIC language interpreters run faster.

Two versions of PATHFINDER as well as MINIMUF have been timed in generating hourly MUF projections. The results of this bench mark over several paths are shown in **table 1**. All results were of equivalent accuracy with no significant discrepancies in projected MUF except where the MINIMUF-85 algorithm provides more credible values. It is evident from **table 1** that PATHFINDER, because it has to set up its variables before path analysis starts, requires more time to return the projection for 0000 UTC. But PATHFINDER quickly generates the MUF projections for the rest of the day. PATHFINDER in either form is comparable or superior to MINIMUF in total response time. PATHFINDER without increased speed would be intolerably slow in executing the MINIMUF-85 algorithms.

The number of control points evaluated on a given path is a significant difference in the three programs. For the short paths all of the programs evaluate at only one point. The two earlier versions determined values

Table 1. Propagation path calculation time (seconds) using three different programs.*

Path	FIRST/TOTAL		FIRST/TOTAL		FIRST/TOTAL	
2000 km midlatitude	<1	49	3	19	3	25
6000 km midlatitude	<1	88	3	31	5	79
6000 km polar summer	<1	90	4	26	6	106
6000 km polar winter	<1	86	5	30	6	91

* "FIRST" is the time needed to calculate the first hour's value.
"TOTAL" is the time needed to calculate the entire day's (24 hours) values.

Bench marks were run on a 2-MHz Kaypro II under Microsoft BASIC 5.2. PATHFINDER-3.5 is based on a MINIMUF-3.5 algorithm and PATHFINDER-85 is based on the MINIMUF-85 algorithm.

at only two points for *longer* paths, while the MINIMUF-85 version of PATHFINDER can evaluate up to 19 points for a nearly circumferential long-path projection. The additional computations required when a point falls within a polar region is another difference. This can easily double the evaluation time per point. The changes appear when radial projections are run since the program must compute a new path and all path and point-related variables with each increment in bearing, in addition to evaluating each point.

program "construction"

PATHFINDER uses the "top-down" programming technique which starts out broad and develops a level at a time. The detail becomes finer for each successive level. The flow of PATHFINDER follows this concept reasonably well. The menu loop is entered after the program constants are set up calling subroutines that call other subroutines until the chosen analysis is performed and the program returns to the menu level.

Looking down inside the input routines, you first have data entry followed by conversions and variable computations for each point. Each input routine processes only its own variables since, with the menu interface, it is necessary to redo some computations previous to or within the simulation setups when input conditions change.

Each of the modes (bearing/distance gray-line, radial and hourly) is driven by an independent setup routine assuring correct results regardless of the others. In this way, you might change the solar flux input and rerun a path evaluation or, once you have a path evaluation, determine the gray-line parameters for the path end points. Each driver sets up the variables necessary for its function and calls the analysis to be executed. The partitioning of the variable setups maintains related computations in the same routine so that duplication of code and computation are minimized, and at the same time, program utility is expanded. Unnecessary computations are bypassed whenever possible.

Table 2. Long-path calculation.*

Propagation for: DEC 21
Home QTH, Lat: −87 Lon: 130
Target QTH, Lat: 80 Lon: 310
Solar flux = 150 Sunspot number = 104
Path length = 12920 miles
Path bearing = 0

GMT	MUF	GMT	MUF	GMT	MUF	GMT	MUF
0000	9.6	0600	8.9	1200	12.5	1800	11.9
0100	10.8	0700	10.4	1300	11.3	1900	12.7
0200	9.5	0800	9.1	1400	10.7	2000	11
0300	9.2	0900	12.8	1500	11.2	2100	10.4
0400	10.5	1000	13.3	1600	15	2200	11.4
0500	9.3	1100	12.7	1700	12.8	2300	10.

*All major program sections are exercised.

code review

The listing for the general version of PATHFINDER is included at the end of this text. This will enable you to develop most hf analyses required. I have chosen to hard code the home station location and eliminate input error checking; items that could be added after the program is running. In the discussion to follow, the only reference to a program section is by its initial line number. A run which exercises all major sections of the program is included in **table 2**.

The declaration and initialization section starts at **fig. 1, line 10**. It sets up the constants and arrays needed, and collects the input required to run a simulation. The main menu selection follows at **line 200**. The menu is multilevel on a priority basis. Each question is answered with one of the indicated option values. Caution: you can only list *after* a MUF simulation has been run. From this point all sections are subroutines involved with program operation. The applications drivers are next: hourly MUF at 1000 (short path at 1010), radial MUF at 1100, gray-line at 1300 and bearing and distance at 1400. Next comes the MUF computation with the MUF setup at 2000, day and darkness critical frequency computations at 2100 and 2200 respectively, followed by the base MUF and FoF2 determination at 2300. The polar model begins at **line 2400** with the final point MUF resolution starting at 2600.

The next set of program blocks represents lower order support for the drivers. At **line 3000**, path bearing and distance are determined. The control point setup starts at 3100. Point latitude and longitude given a bearing and distance from a reference point are computed in the subroutines starting at 3300 and 3400, while the subroutine at 4000 determines the number and spacing of the control points and calculates the M-factor from the path information. **Line 5000** enters a routine to characterize the aspects of solar illumination of a point. Two math routines are next; the ARCCOS function at 6000 and a range limiting function at 6100. The "soft" output routines follow: gray-line at 7000, bearing and distance at 7100, and simulation base at 7200. The input routines are last: date at 8000, solar factors at 8200, and target location at 8300. The last line of the target routine starting at 8320 is used as a subroutine by the analysis drivers to assure correct target location definition. This is necessary because the radial MUF routine redefines the target longitude with each bearing increment.

Significant gaps have been intentionally left in the program line numbering sequence. This allows ample room for program expansion and makes program segmentation easier. All listings in this article are presented in Microsoft Extended BASIC-80 version 5.2 for a CP/M 2.2 operating system. This is a universal programming language that may have some features and syntax not shared with other dialects of BASIC. One problem may arise with the ON-GOTO/GOSUB constructs used in the menu; they may have to be replaced with a chain of IF-THEN statements for other systems. Please refer to the user manual of your BASIC language during conversion. This version of PATHFINDER has been submitted to the ARRL Program Exchange along with several conversions including one written in TURBO PASCAL™.*

experiences with PATHFINDER

Art Allen, KY1K, mentioned that there was a lot of activity on 20 meters to the western Pacific one morning in late June. PATHFINDER confirmed for Art that the mode was long path and that it also covered Japan and parts of UAO land. The short path MUF to those locations was at or below 8 MHz at the time while the long path MUF was well above 10 MHz.

K3RN, Bob Newkirk, spends a lot of time on the air at daybreak. I ran a gray-line summary for him last year using a version of PATHFINDER with access to a world latitude/longitude data base. Bob's country total is already high so it didn't net him any new ones but the projections were "just about right on" and gave him a couple of weeks of fun checking out my data.

In the week before Field Day 1987, I used PATHFINDER to track and characterize the MUF for W1KVI (Portland Amateur Wireless Association). I generated point-to-point reports for 15 paths between 500 and 2500 miles as well as radial reports for these distances at four-hour intervals. Trends suggested by these projections were as follows: 20 meters would be poor from 0400 through 1100 UTC, the West Coast would not be strong on 20 and propagation for that band would favor the 1300 to 1800 mile range; 15 meters also indicated some promise around noon in the 1800 to 2600 mile range. These projections were very close as indicated by contacts in our logs.

Success with the MINIMUF ionospheric models in PATHFINDER lies in the interpretation of all the factors involved. The MUF report is not 100 percent accurate: one must consider the absorption characteristics indicated by the K and A indicies; watch the path build up and decay over time; and consider the paths to adjacent areas in order to get a good feeling for what the computer is telling us. By providing the ability to run several types of analyses within one program, PATHFINDER can help determine the probability of working that new country.

summary

PATHFINDER is a general hf operating aid capable of providing MUF analysis modes as well as gray-line and bearing/distance reports. It uses MINIMUF-85 algorithms and has been optimized for both utility and speed. There is an elementary, menu-driven, top-level program allowing you to change input data, run, and report analysis at will without having to restart. By running several types of evaluations in the same session, you will gain a better appreciation for what is going on in the ionosphere.

Available publication space has required that the code for PATHFINDER presented in this article be rather spartan. In the future I hope to provide the code necessary to build and access a latitude/longitude data file as well as make use of the MOUT(x) array for simple graphical presentation of the simulation results.

I have had a lot of fun with this project and am more

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*TURBO PASCAL is a registered trademark of Borland International, Inc., Scotts Valley, California.

than satisfied with it. I wish to thank all those who contributed to PATHFINDER including: K6GKU for time and much effort in reviewing the manuscript and program, and K1ME for the use of his TNC in transfering the program to AJ1T for the Commodore conversion. Thank you and happy DXing.

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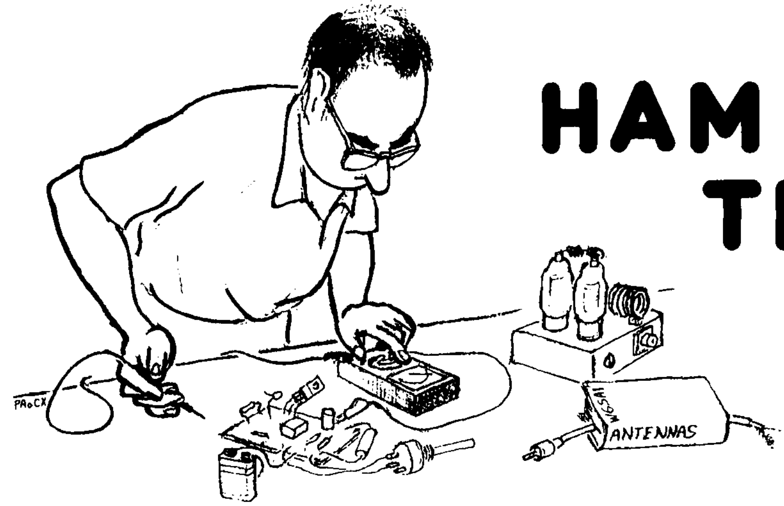
ham radio



HAM RADIO TECHNIQUES

Bill Orr, W6SAI

why not a two-element Yagi?

Many years ago my three-element 20-meter Yagi suffered severe damage in a furious wind storm. I was able to get the wreckage down before the winter weather set in, but the chance of getting the antenna repaired and back atop the tower were slim, considering the ominous weather reports. As a stop-gap measure, the beam was converted to a two-element array on a short boom which could quickly be carried to the top of the tower by a single person. This seemed a reasonable, short-term solution, so I took it.

I was pleased with the results achieved by the small beam. It worked so well that it was many months before the larger three-element beam replaced it.

Nevertheless, the two-element Yagi has faded into relative obscurity. Popular in the fifties when few commercial beams were available, it disappeared with the advent of manufactured antennas. Lately there has been renewed interest in the little antenna; more and more newcomers to the 10-meter band are erecting two-element beams and having excellent results with them. I hit the band a few months ago with a compact two-element antenna and was flooded with questions about it. Here is the story of this small, inexpensive Yagi with a big punch!

the two-element Yagi for 10 meters

As compared with a three-element beam, the two-element Yagi is lighter, smaller, has less wind resistance, and can be built easily and inexpensively. The antenna has a single director spaced 0.1 wavelength in front of the driven element and a theoretical gain of about 5 dB over a dipole with a front-to-back ratio at the design frequency of about 13 dB.

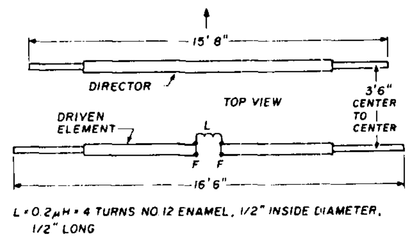


fig. 1. Layout of 2-element, 10-meter Yagi. Coil L is placed across feedpoint F-F to achieve good match. Wind coax transmission line into choke coil (4 turns, 8″ diameter) at feedpoint.

In comparison, a three-element Yagi on a 0.25 wavelength boom with equal spacing between elements has a theoretical gain of about 7.1 dB over a dipole and a front-to-back ratio at the design frequency of about 23 dB.

The two-element Yagi has about 2 dB less gain than the three-element antenna, and has a front-to-back ratio about 10 dB poorer. However, the boom length of the two-element beam is only 40 percent of the larger array. This is important in areas with high winds. Some Amateurs, particularly those living in the Midwest, require as much front-to-back ratio as they can get because of interference from both the East and the West. In other areas of the country, the Amateur can opt for the smaller array without losing very much in antenna performance.

building a two-element 10-meter Yagi

Assembly information for a compact, 10-meter Yagi is shown in **fig. 1**. The design frequency is 28.4 MHz, making the antenna suitable for CW, Novice, and regular Amateur service from 28.0 to about 28.8 MHz. The feedpoint resistance of the antenna is about 17 ohms. Element spacing, center-to-center, is 3 feet 6 inches.

Raise the feedpoint impedance to 50 ohms by shortening the driven element slightly to make it capacitively reactive at the design frequency, and place a small inductor across the feedpoint. This arrangement comprises a simple impedance step-up L-network. Wind the coax transmission line into an rf choke at the antenna feedpoint to preserve feedpoint balance and decrease the chance of rf getting into the shack.

Array construction is greatly simplified by using a wood boom and wood brackets for element support **(fig. 2)**. My boom is made of a length of well-dried, two-by-two lumber that was sanded and given two coats of marine varnish. The element supports are 16- by 3-inch lengths of finished wood (5/8-inch thick), painted with varnish and fixed to the boom with glue and small nails or screws.

Fasten the boom to the mast with a gusset plate made of 5/8-inch thick plywood. Because this material can disintegrate quickly unless it is protected from weathering, seal the edges with two coats of wood preservative and give the whole plate two coats of outdoor house paint. Fasten the boom to the plate, and the plate to the mast, with pairs of galvanized U-bolts. Use washers and lock washers on all bolts to make a rigid joint.

Attach the elements to the wood crossarms with either U-bolts or homemade clamps made of scrap aluminum. (I had no luck finding U-bolts that matched the diameter of the element; however, once the beam was up in the air the correct size U-bolts magically showed up at several hardware stores.)

assembling the elements

The elements are made of three sections of commercial grade 6061 aluminum tubing. Use a 12-foot length for the center section and short, telescoping sections of tubing for the tips. The center section of the element is 5/8-inch diameter tubing, with a wall thickness of 0.058 inch so that the 1/2-inch tubing will easily telescope within it. (Any diameter tubing will fit into the next larger size if the larger size has a 0.058-inch wall thickness.) The end sections are 1/2-inch diameter tubing with 0.035-inch thick walls. The tips have thin walls to decrease weight.

To lock the tubes in position, use a hacksaw to cut a narrow slot about a foot long in the end of the center tube, through both walls, on a line with the center axis of the tube. Remove all burrs from both the inside and outside walls; then sand and clean the tips to lessen the possibility of seizure after the tubes are telescoped. Make the slots wide enough so that when pressure from a hose clamp is put on the walls of the outer tube, the inner tube is held firmly in place.

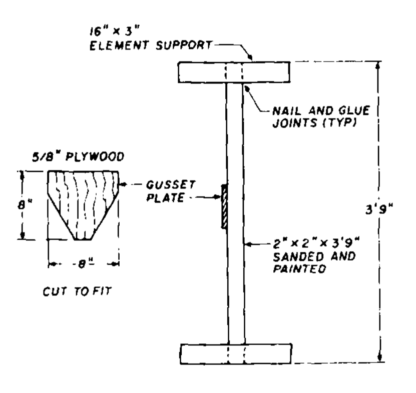


fig. 2. Boom details for 10-meter beam.

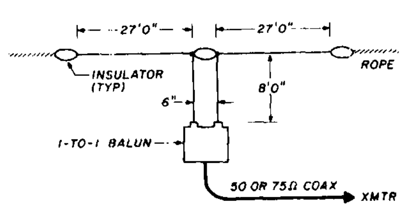


fig. 3. 7- and 21-MHz broadside antenna.

Smear a small amount of anti-oxidizing compound over the end of the smaller tube to prevent corrosion and oxidation of the joint between the tubes. This lubricant is commonly used in industrial power installations and sold by large electrical supply houses. Some trade names are Penetrox™, Cual-Aid™, and Ox-Guard™. The compound is a good electrical conductor and ensures a trouble-free joint. A small tube of the paste is sufficient for three or four antenna arrays.

Split the driven element at the center to provide a feedpoint. Separation between the sections is about an inch. To preserve alignment, force the element sections on a short wooden dowel that has been given two coats of varnish for weather protection. Drill the element ends for bolts and nuts to provide a connection point for the feedline.

Bolt the matching coil across the feedpoint like the coaxial line. Prepare the line by skinning the outer insulation back a few inches. Unbraid the outer conductor by using a small nail to separate the wires. Twist the wires into a pigtail and place a solder lug on the end of the tail. Place a second lug on the center conductor of the line. Waterproof the end of the line by covering it with Coax-Seal™ or wrapping it securely with vinyl tape. Make sure that water cannot enter the end of the line — it would quickly corrode the conductors.

Finally, wind the coax line into an rf choke just before it attaches to the driven element. Six turns of line wound into a coil whose diameter is twelve times the diameter of the coax will suffice. Hold the coil in place with vinyl tape.

erecting the beam

A heavy-duty TV rotator turns the beam. Make sure the one you use has a lock so that the antenna will not "windmill" when the rotor power is off. Mount the antenna to a short vertical pipe that fits the top section of the rotor.

The antenna can be as low as 16 feet above ground for good results around the United States. You can mount it relatively inconspicuously just above the roof of a one-story dwelling. A height of 25 to 40 feet is recommended for better results. When building and testing the beam I had it mount-

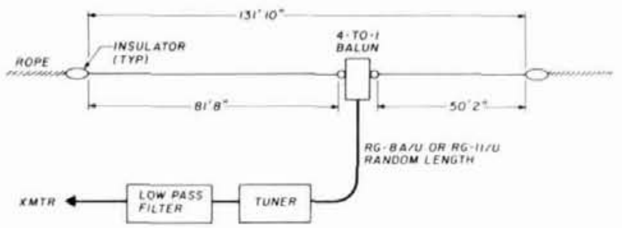


fig. 4. The "Carolina Windom" antenna works 80-10 with tuner. WA4LVB recommends that the antenna be 35 feet or higher above ground.

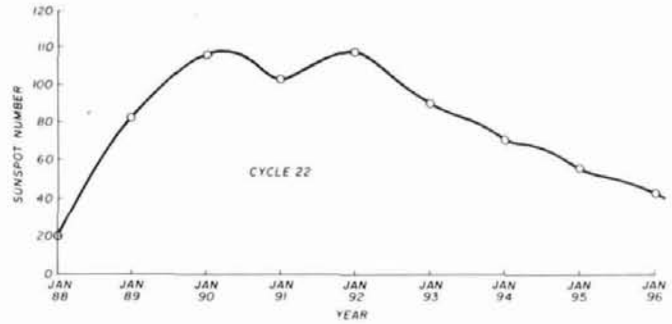


fig. 5. National Bureau of Standards forecast for sunspot cycle 22 based on data as of August 1987.

ed atop a 6-foot step ladder. Even at that low height I was able to make many contacts nationwide with good reports, so don't let height restrictions stop you from considering this project.

adjusting the beam

The beam as described probably won't require any adjustment. It provides a bandwidth of about 800 kHz between the 2:1 SWR points. However, any antenna is sensitive to the immediate environment and to the height above ground. Check the SWR from 28.0 to 29.0 MHz and make a chart of SWR reading versus frequency. It should be a smooth curve, with a minimum SWR figure near the design frequency of 28.4 MHz. If the SWR at the design frequency seems too high, adjust the spacing of the matching coil turns slightly, or increase or decrease the number of turns. The length of the driven element can be adjusted to bring the minimum SWR point to the desired frequency, but in the majority of cases these adjustments will not be required.

compact 7- and 21-MHz antenna

This wire antenna, designed by G3TKN, fits into a 55-foot span and works on two bands. It is a 7-MHz dipole with the center section folded up to form a simple matching stub on 21 MHz, where the antenna operates as a two-element collinear array providing about 3 dB power gain. Antenna dimensions are given in **fig. 3**.

The center stub is made of two No. 14 enamel-coated wires with a 6-inch separation. Three spreaders are required and can be made from plastic rod or 3/8-inch diameter wooden dowel. Give the wood a weatherproof coat of varnish. Pass the wire through holes drilled in the ends of the spreaders. Hold it in place by winding short lengths of No. 22 wire around the dowel and the stub wire passing through it.

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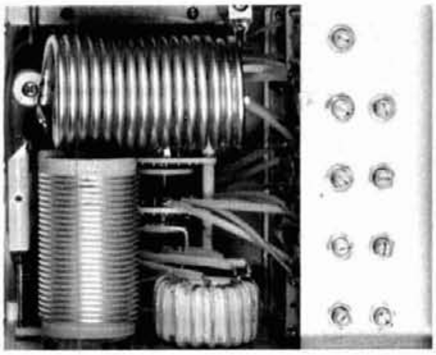

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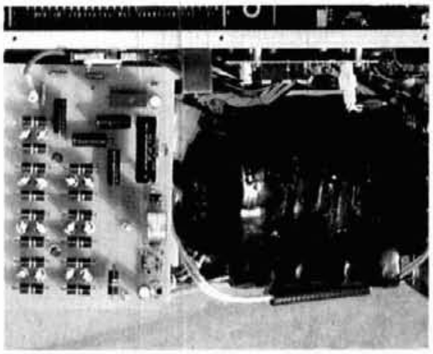

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Feed the antenna with a 1:1 coax balun and a coax feedline. Optimize feedline SWR on 21 MHz by varying the length of the stub an inch or two at a time. The antenna performs well when elevated 30 feet, or higher. On 40 meters the pattern is that of the conventional dipole; on 15 meters it is also bidirectional but with sharper lobes.

the "Carolina" windom antenna

This antenna, popularized by W8GZ* in the early twenties, is still with us in various forms. The latest idea was sent to me by Edgar Lambert, WA4LVB. It seems the idea was conceived by W4UEB, WY4R and WA4LVB. The antenna is shown in **fig. 4**. The flat top is cut for 3550 kHz and is off-center fed with a 4:1 balun and a coax line. Since Edgar told me about it, I have heard several of these antennas on 20 meters and they seem to poke out a good signal. Edgar says it's a good approximation of the mythical "all-band" antenna. Maybe so. Why don't you try it out and send me your results?

sunspot cycle 22 coming up!

At last! Old sunspot cycle 21 ended about September, 1987. There's no doubt about it. Ten meters has been "hot" since the fall of 1987. Happy days are here again!

While 10, 12, and 15 may be "flat" during the summer months, there will be plenty of sporadic-E short skip to liven up the bands. They will come alive with a bang in mid-fall!

So what are the prospects for the next sunspot cycle: cycle 22? The Space Environmental Services Center of the National Bureau of Standards predicts the next cycle will peak in 1990 through 1992 with a plateau of about 110. The general prediction for cycle 22 is shown in **fig. 5**. It seems as if 10 meters will be a good DX band until at least 1997! That's nine years of good DX conditions ahead for Amateur Radio. I'll drink to that!

ham radio

***ham radio** regrets that L. G. Windom, W8GZ, died on February 1, 1988.

the Quad antenna: part 1, general concepts

A comprehensive study of this popular antenna

This is the first in a series of articles on the Quad antenna family. In this series I will attempt to:
- clarify the concepts of Quad family antenna design.
- set forth Quad theory to the extent needed for practical design.
- provide easily used design data for a range of practical designs, medium frequency (mf) to very high frequency (VHF).
- provide data on practical construction to eliminate current physical weakness problems.

Included are:
- concepts of the loop family
- circular loops; octagonal loops
- circular loop arrays; octagonal arrays
- the Quad loop family
- arrays of Quad loops
- the triangular loop family
- triangular loop arrays
- ground effects on loops and arrays
- multifrequency loop designs
- other loop designs
- loops and array construction techniques

There will be several installments on the elements of theory and design data, each dealing with a single member of the Quad family.

Quad versus Yagi

The Yagi is the most popular type of Amateur directive antenna. Surveys on the hf bands show that over half of all stations use some form of Yagi. Three-element triband designs with traps for band isolation are the most common.

The Quad, second in popularity, is usually a two-element design using the square configuration. Many are single band, others are two or three single-band antennas on a common boom. True multiband Quad elements have been designed, but are rarely used.

The lower portions of the hf band tend to favor delta or triangular loop Quads that need only a single high support. The circular loop is popular on VHF. But total usage is about one-fourth that of the Yagi — some 12 to 15 percent of all installations (this includes all types of antennas, not just Yagis). Commercial use of Quads is limited and they are relatively low sales items on the Amateur market.

The pros and cons of using a Quad are often debated. The most common reason given for using a Quad is that it is a good directive antenna which can be built from locally available materials. It's fun to experiment with and has a reputation for good performance at low height. Long-time Quad users seem to stay with the design because they like the performance.

Three reasons usually given for not using a Quad are: susceptibility to damage during high winds, lack of space, and lack of design data for the high-performance types. In actuality, these are weak reasons for rejecting this antenna. First, the wind damage factor can be reduced by solving aerodynamic and mechanical design problems. Second, for a given gain, the Quad can have a smaller turning radius than a Yagi. This allows it to fit into smaller places, and makes it easier to obtain gain at lower frequencies. Finally, there is an enormous amount of literature covering all elements of Quad theory, design, performance, and construction.

Unfortunately, Quad literature tends to be fragmented. The theory and most precise design and performance data are written by scientists and engineers; the practical construction data appears in Amateur

By R.P. Haviland, W4MB, 1035 Green Acres Circle North, Daytona Beach, Florida 32019

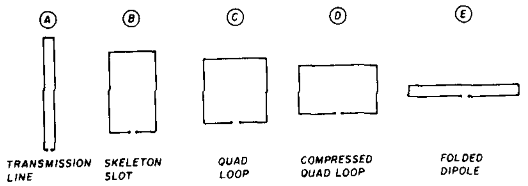

fig. 1. The square (4-sided) Quad family, conceptually formed by separating the sides of a two-wire open transmission line shorted at the far end. As a first approximation, all members behave as a transmission line.

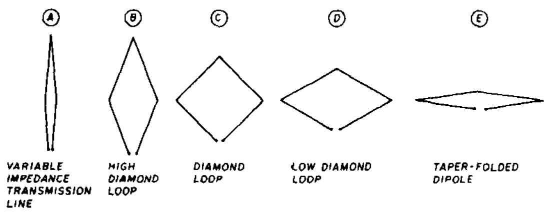

fig. 2. The diamond Quad family, formed by changing the separation of transmission line sides at the midpoint. Again, all members behave as a transmission line. Properties are very close to those of the square Quad family.

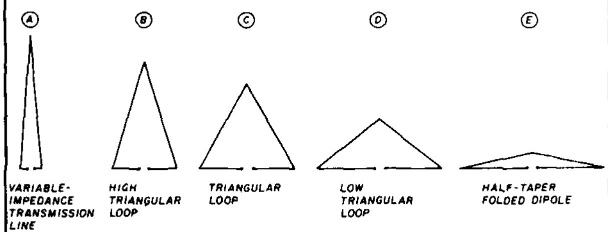

fig. 3. Triangular loop family, formed by changing the transmission line spacing at the feed point. Transmission line behaviour indicates that the performance will be similar to the square and diamond loops.

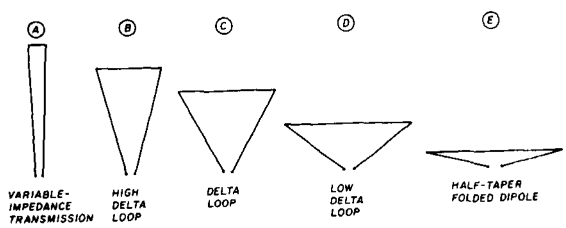

fig. 4. Triangular or the delta-loop family. Transmission-line spacing change is at the far end of the line.

Radio publications. The scientific data are hard to use in a practical sense because computers are needed to derive useful design values.

shapes of the Quad families

One of the easiest ways to approach the Quad concept is to start with a length of open-wire transmission line, shorted at one end and with a generator at the other, as shown at A in **fig. 1**. If the spacing between the sides of the line is progressively increased, the shapes of B to E successively develop. These shapes are representative of the rectangular Quad family. From A to E, the shapes are:

A shorted line
B skeleton slot
C Quad loop
D compressed Quad
E folded dipole

Instead of keeping the sides of the figures parallel, we could choose the midpoint of the sides as the point of inflection and create a second family with diamond-shaped members (**fig. 2** A to E). The center shape is the only one commonly named, the diamond Quad.

When three points of inflection are used instead of four, the result is two families of triangles as shown in **fig. 3**, A to E, and **fig. 4**, A to E. The center triangles in each figure are generally called delta loops, and are distinguished by whether they are fed at an apex or the midpoint of a side.

You can use more than four points of inflection. At the upper limit, the sides become smooth curves — the ellipses and circle of **fig. 5**, A to E. At the extremes, A is still a shorted transmission line section and E is a folded dipole.

It is not required that the shapes remain symmetrical, that the conductor always be along the perimeter of the figure, or that no part of the figure be re-entrant. Three possible shapes are shown in **fig. 6**. A is an acute triangle, B is a bent-side or bat-wing Quad, and C is a "line shortened" Quad.

The element need not be confined to a plane. The G4ZU Birdcage and the Swiss Quad, examples of non-planar elements, are basically variations of the bat-wing element of **fig. 6** with the apex of the bent element pulled out at right angles to the paper.

Finally, simple and symmetrical shapes are not the only ones that may be used. **Figure 7** shows some other designs: A uses a transmission-line section to reduce size, and B and C use a form of capacitive hat for the same purpose. D uses a form of open-wire feed to give choice of polarization.

conceptual approach to Quad performance

The end points of the major Quad families have well-known characteristics, providing a basis for a concep-

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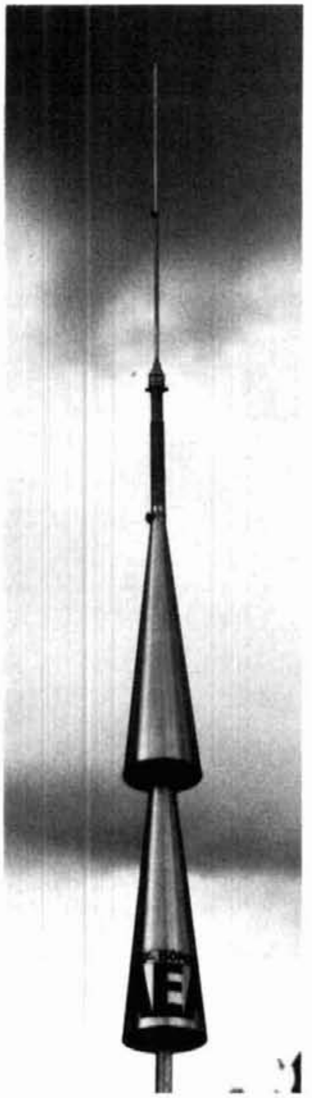

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IsoPole Specifications

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2.1 VSWR bandwidth	)12Mhz @ 146Mhz	)15Mhz @ 220Mhz	)22Mhz @ 435Mhz
Power Rating	1 kw	1 kw	1 kw
Gain**	3 dbd	3 dbd	3 dbd
Radiating Element Length	125.5" (3.2m)	79.25" (2m)	46" (1.2m)
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**dbd — db gain over a dipole in free space

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AEA Brings you the Breakthrough!

tual approach to Quad performance. Let's start by looking at the shorted transmission line.

First, suppose the generator frequency for the line of **fig. 1A** is varied. At very low frequencies, any practical line is basically a short circuit and has little effect. The resistive component of impedance is small, essentially zero. The reactance is also small, and inductive.

Both resistance and inductive reactance increase with frequency. This increase continues until the line becomes one-quarter wave long. At the frequency where this occurs, the input impedance is very high, and purely resistive. The line acts as a parallel resonant circuit. This is also known as the first resonance point.

For still higher frequencies, the resistance decreases, and the reactance decreases from its infinite value, but is now capacitive. When the line is one-half wave long, the reactance again becomes zero. The input resistance would be zero for a lossless line. This is the first series-resonance point. At slightly higher frequencies, the resistance and reactance increase, and the reactance is (again) inductive.

The pattern of alternating low and high impedance, and inductive and capacitive reactance, repeats at increasing frequencies. **Figure 8** shows the pattern with the peaks and nulls marking additional resonances.

At the other (shape) extreme is the folded dipole of **fig. 1E**. At low frequencies, its input resistance is very low. Its reactance is high, and capacitive. The antenna looks like a small capacitor in series with a small resistor.

Reactance decreases and resistance increases with increasing frequency, until the antenna is somewhat less than a half wavelength overall. At this point the reactance is zero, and the resistance is very nearly 300 ohms, just four times the resistance of a resonant single-wire antenna. This is the first resonance point.

At still higher frequencies, the resistance continues to increase. The reactance also increases, but is inductive in sign. With the antenna just less than a full wave overall, reactance again becomes zero, and impedance is very high.

This pattern also repeats, at close to each half wavelength. The points of low impedance and zero reactance mark the second, third, etc. current-feed resonances, and the high impedance points to the voltage-feed resonances.

frequency/size/pattern relationship

Before going on, let's consider the effect that changing frequency (or size) has on the radiation pattern.

At frequencies small compared to first resonance, the current on all parts of the wire will be nearly equal in magnitude and phase, as indicated for the loop in **fig. 9**. For a point on the loop axis, at right angles to the plane of the paper, the field contributions of the eight points of current shown appear as in the small vector diagram, and add up to zero. In the plane of the paper, the components from the near and far side of the loop have an out-of-phase component, because of the time required for a radio wave to travel across the loop. A doughnut-shaped pattern results. The hole axis is at right angles to the plane of the paper.

These very small loops will radiate well, but will be difficult to feed because they have very low resistance — not much more than the conductor itself. Loss in the matching system will be high.

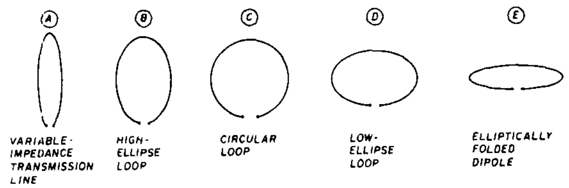

fig. 5. Circular-loop family, formed by smoothly changing the transmission line spacing. For a given length of conductor, the circle has the greatest area, and will show higher gain than the square. (For the same given perimeter, the area of a circle is 27 percent greater than that of a square.-Ed.) However, the figures with greater separation of the current maxima can show still higher gain: this is true for all loops.

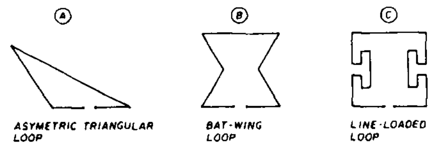

fig. 6. Examples of other possible shapes. In each case, the area in the figure is less than that for a corresponding simple symmetric member. This reduces gain below maximum (possible), but allows attainment of some other objective, such as small size or use of a given support.

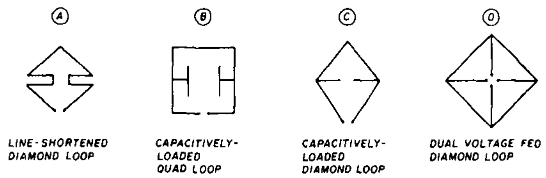

fig. 7. More examples of special shapes, all using some form of loading to reduce antenna size. Line sections can be replaced by inductors, and the capacitive sections by actual capacitors. The fourth shape uses the capacitive lines as the feed point, to allow horizontal or vertical polarization.

117

145

146

118

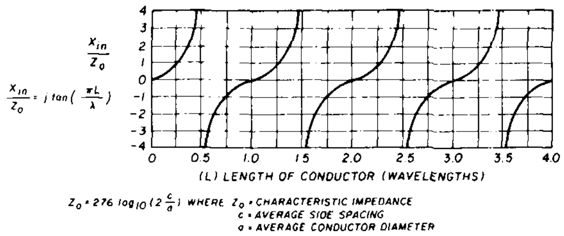

fig. 8. Generalized terminal reactance of a two-wire transmission line. The characteristic impedance is determined by wire size and spacing. From the standard formula, $Z_0 = 276 \log (2\frac{c}{a})$, c being the separation and a the wire diameter. Use the average separation for nonparallel-sided lines. Lacking other data, use this curve to give (approximately) the feed-point reactance for any member of the Quad family of loops.

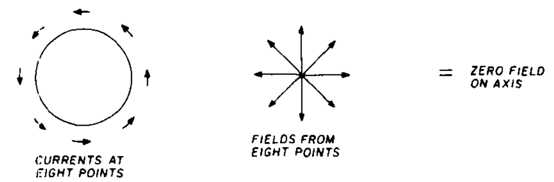

fig. 9. Vector field pattern of small loop, showing that the fields from individual wire segments cancel for on-axis radiation. The resultant field is doughnut shaped.

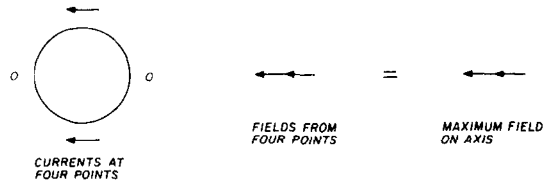

fig. 10. Vector field pattern for a one-wavelength loop. Components from the loop top and bottom add to form a major lobe on axis. The components at 45 degrees do not completely cancel, so there is a small doughnut pattern of vertically polarized radiation.

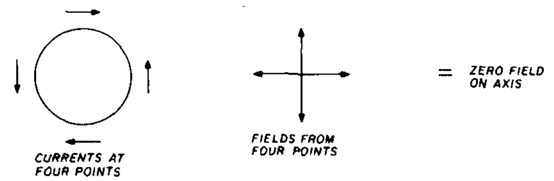

fig. 11. Vector-field pattern for a two-wavelength loop. Components on axis cancel, but add to form a double cone-shaped pattern. Cancellation of on-axis radiation occurs for wire lengths of three or more integral wavelengths also.

At frequencies close to first resonance, maximum current will occur at the feedpoint and half-way around the loop from it, as shown in **fig. 10**. The major field components from the upper and lower parts of the loop, on axis and at right angles to plane of the paper, are now in phase. In the plane of the paper, the components on the line of maximum current are out of phase. Maximum radiation is at right angles to the loop, and is horizontally polarized.

There are small components of current on the vertical parts of the loop. These are equal and opposite in phase and form a vertically polarized pattern. Most Quad analyses neglect this component, since it is much smaller than the main lobe. Its practical importance is not clear, but it may be responsible for creating the reputation of the Quad as a good performer at low heights and under marginal conditions.

For frequencies close to second resonance, maximum currents occur at each one-quarter point around the loop (**fig. 11**). Because currents on opposite sides are equal but opposite in phase, there is no net radiation on the loop axis. Maximum radiation occurs in the plane of the paper, with lobes of 90 degrees each. This is the general pattern for all resonances higher than the first, with the number of lobes equal to twice the order of the resonance. The pattern is the same for all simple shapes.

The considerations above indicate that the primary area of interest for the Quad family of **figs. 1** through **6** will be at or near first resonance, where the lobe structure is simple and on the axis of symmetry. For all of these shapes, the total conductor length is very close to one wavelength.

Quads with conductor lengths of two or more wavelengths don't have useful radiation patterns at right angles to the loop plane. One exception occurs if the basic transmission line is open circuited (**fig. 12**). The first, or serial, resonance point isn't too useful. The next (or parallel) one gives a simple lobe structure on the axis of the loop, which is useful in itself or as a switched open/shorted two-frequency loop. This was the basis of the now rarely used bi-square beam.

drive resistance relationship

The input resistance of a shorted one-half wave transmission line is almost zero (see discussion referring to **fig. 1**). For the folded dipole, the drive resistance is about 300 ohms. Considering that the currents in two wire segments interact less the further they are apart, we expect the input resistance of the intermediate shapes to fall between these limits. For the shapes designated as C, the input resistance should be near 150 ohms. The resistance will be lower for the skeleton slot, or B types, and higher for the squashed D types. The exact pattern of variation must be worked out.

drive reactance and resonance relationship

Antenna resonance is defined by zero input reactance. All of the shape variations will have a specific point or points of resonance, and we can't expect them to be independent of conductor shape. For a shorted, air-insulated line, resonance will be very close to the physical half-wavelength point. The resonant frequency of a folded dipole will be some 5 percent lower. Because we don't know the current change due to variations in the separation of current points, we must determine the effect of changing shapes.

The magnitude of reactance change in moving away from resonance involves cosine functions. For small deviations from resonance, it is reasonable to expect that the reactance can be approximated by a simple linear function. The reactance, then, can be specified by two values — the frequency of resonance and the slope of the reactance curve. We must see if an additional simple function for shape can be developed.

gain relations near resonance

We can look at the gain from two viewpoints. The first is based on element separation. The gain of the shorted line section is zero, because the radiating section is approximately zero length. As we move toward other shapes, the radiating length increases, but the spacing between the two high-current sections decreases. As the shape approaches that of the skeleton slot, there will be two well-separated high-current sections of reasonable length. The gain should approach twice that of a simple dipole.

At the other extreme, the gain of the folded dipole is the same as a simple dipole. Thus, we expect a gain decrease when going from the very tall, narrow slot toward the dipole. Overall, the gain should increase slowly as the sides of the dipole are pulled apart, reaching a maximum at some separation, and then falling to zero gain. However, without some other guidance, we cannot state the gain of intermediate shapes.

A second way of looking at this gain variation is from the view of the effective area. Considering just the high-current part, the area measured in average amperes times electrical degrees of length will be nearly zero for the shorted line, unity on a per unit scale for the folded dipole, and basically two for the shapes (C). Thus we expect the gain of an optimum member of the Quad family to approach 3 dB above an isotropic. The circular loop should have the best gain, the rectangular one slightly lower, and the delta loop lower still. However, all nearly symmetrical shapes should show some gain with respect to a dipole.

Further consideration of the same area indicates that the gain of the resonant open-circuited (two wavelength) square should approach 6 dB above an isotropic at parallel resonance. We would expect many of the odd and re-entrant shapes to have gain, but the ones with small area will show a loss compared to a dipole.

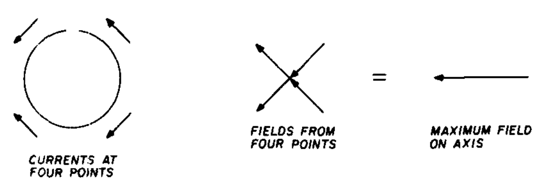

fig. 12. Vector field pattern for a two-wavelength loop formed from an open transmission line. The components add to produce an on-axis lobe. This lobe exists for longer wires also, but there are also added lobes.

Quad elements in beams

Any of the above shapes can be used in either a driven or parasitic beam. One way of looking at such beams is to assume that the radiation effect of each element is the same as if it comes from a point source located at the center of electrical symmetry of the element. This leads to the concept of pattern multiplication, where the overall pattern is the product of the element pattern and an array pattern, as determined by the relative spacing, current, and phase.

Because array patterns are well known (and quite simple in many cases), beam patterns will be easy to develop when the element patterns are worked out. There is, however, a corollary to this. Any unusual benefit from the Quad family will have to come from the elements themselves and not from the fact that they are assembled into an array.

In this simplified consideration, some gain above a dipole has appeared. It is expected that a Quad array can be shorter than an array of dipoles (Yagi) and still achieve the same gain. Although the vertical height is much greater, the horizontal span and the turning radius are less. For a given gain, Quads require less space.

neglected factors

A number of implicit assumptions were made in the preceding paragraphs. One is that the conductor has no loss, and is very thin. Currents were assumed to be sinusoidal. Small pattern factors, like the lobes in the plane of the elements, were ignored. These are important in a detailed analysis, but should represent only variations from simply derived values and not major changes.

Part 2 will cover the theory of circular elements and the beams constructed from them.

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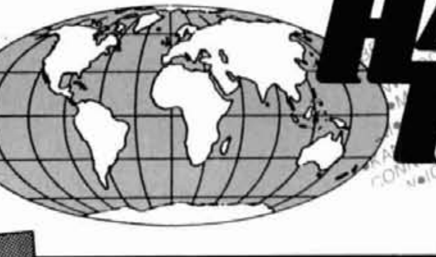

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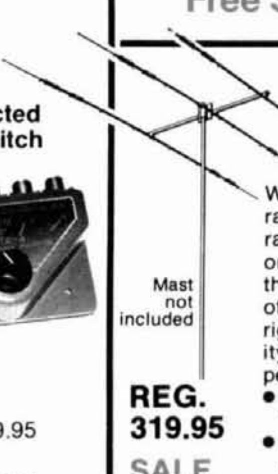

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short circuits

SM6CPI November 1987

In fig. 1 of SM6CPI's November, 1987 article, "A CAT Control System for the Yaesu FT-757GX," you may like to make one or two changes in line 4107. The first is related to the word format and the second should is only for C-64 machines made for the NTSC TV system, which have a slightly higher clock frequency than the PAL versions available in Europe. After the changes the first part of the line should read:

4107 DATA 195,255,96,128,0,6,0, 0,206,........................

You should also change the check sum (22360) in line 10020 correspondingly: to 22492 in the NTSC version or 22488 for a PAL machine. Neither of the two data seems to be critical in the present application, but they may create some confusion if you want to use the subroutines in other programs.

K7NH December 1987

In the article, "A Simple rotor interface board for the C-64 and the VIC-20," by Neil Hill, K7NH in the December 1987 issue three corrections to the diagram reproduced on page 18 are required:

Four jumpers are indicated but only the first three (counting from the left) should be used.

The change you need to make is a tricky one, so work carefully. Instead of connecting the jumpers to the land above (as shown in the diagram) connect all three to the land immediately to the right of their present (top) connections (in all three cases). If you haven't already, *do not* install the fourth or right most jumper. If you have, remove it. If you can't visualize the changes, send for our simple sketch.

N6GN February 1988

Some omissions and errors crept into Part 1 of "Designing a Station for the Microwave Bands" in the February 1988 issue.

On page 52, although many parts had labeled values in **fig. 4**, the material list was not included. It is as follows:
R42/45 and C32/33 are from **table 6** or calculated as shown in text,
U1,2,6 are 1/3 10116 ECL Line Receiver,
The extra gain of U2 is required when using harmonic downconverters,
U3,4 are OP07, 741 or similar opamp,
U5 is 12040 ECL Phase/Frequency Detector.
Jumpers on U5 pins 6 and 9 are connected as follows:

f_{RFH} relative to f_{POF}*	oscillator tuning sense (MHz/volt)	
Below	+	−
Above	−	+
*f_{RFH}	PLL downconverter reference frequency	
f_{POF}	Phaselocked oscillator frequency	

In the schematic, **fig. 4**, U4 has its inverting and non-inverting inputs shown reversed. The same circuitry is shown correctly in **fig. 6**.
Resistors may be 5 percent tolerance or better.
Similarly for **fig. 5** on page 58 the material list should be:
CR1 is Motorola BB105 UHF TV tuning varactor or similar,
L3 is 4-1/4 turns No. 28 on 5/32 inch form with adjustable core 180 nH nominal,
U7 is 1/3 of 10116 ECL Triple Line Receiver,
U8 is 10138 bi-quinary ECL divider,
Y1 is 100 MHz 5th overtone series resonant crystal.

The values for R42/45 in **table 2**, page 60, should be 25k ohms and 1.1 K ohms not 25 and 1.1 ohms as shown. Some omissions from **table 1**, page 44, will be included in a later part of the series.

editor

the ham notebook

three-band sloper for 7, 18, and 24 MHz

Anticipating the activation of 18 MHz for United States Radio Amateurs and because I needed an antenna for 24 MHz, I built the sloper shown in **fig. 1**. On 24 MHz the 27-foot, 10-inch section is three quarter waves long. The 24-MHz trap isolates the remainder of the antenna on this band. On 18 MHz the entire antenna again resonates as three quarter waves. On 7 MHz the antenna is roughly one quarter wavelength long and provides a low SWR.

The sloper is hung from the top of a 40-foot tower which supports a three-element tribander. My sloper produced SWRs of 1.5 or less across all three bands. Pruning the 4-foot, 10-inch section and adjusting the slope affects performance on 7 and 18 MHz.

The inductance L is ten turns of No. 14 wire on a 1-5/8 inch diameter form. The 2-inch long coil has an inductance of 2.2 μH. The capacitor (see **fig. 2**)

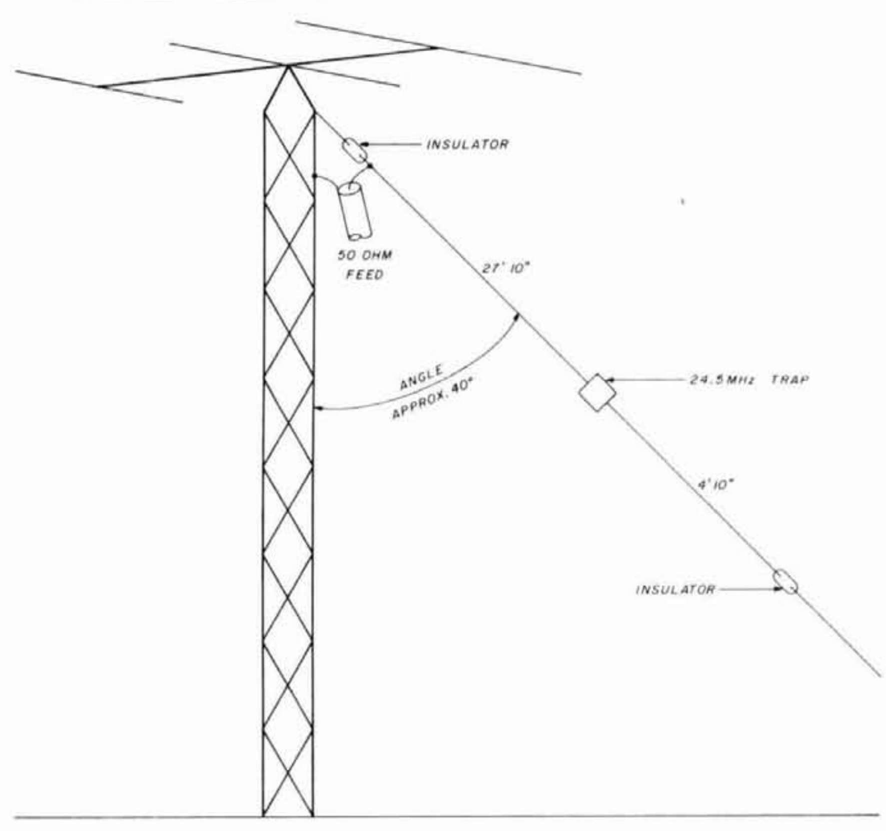


fig. 1. Sloper configuration.

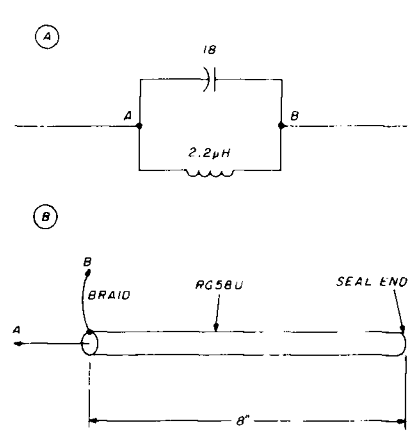


fig. 2. Trap details.

is approximately 8 inches of RG-58. Prune and adjust the trap with a GDO to 24.5 MHz.

Jack Najork, W5FG

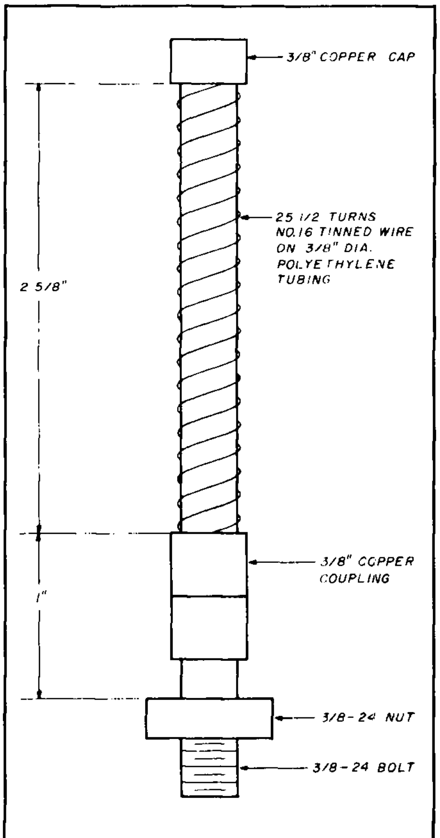
miniature 2-meter mobile antenna

A full-size 2-meter mobile antenna is not needed to work local repeaters, and may be undesirable. I had to remove my 5/8-wave thread-mount antenna every time I garaged my van, so I stopped using the rig on short trips. A highly visible mobile antenna can also be an invitation to thieves and vandals. Considering the options, I realized that since I could work my favorite 2-meter repeaters using a rubber duck on a handheld, a similar antenna would do at least as well on the van.

Figure 1 shows the construction. To make a threaded base for the antenna, I sawed the head off a 3/8-24 bolt and soldered on a stopnut. A coupling for 3/8-inch copper tubing was soldered to the bolt. Three and one-half inches of 3/8-inch diameter polyethylene tubing was inserted into the coupling to support the coil — made by close winding 32 turns (about 38 inches) of No. 16 tinned wire on a 3/8-inch drill bit. I slipped it over the polytubing and stretched it for a tight fit. A copper tubing cap was used to terminate the top of the coil in a small capacity hat.

I tuned the antenna by alternately measuring SWR and tack soldering bits of wire between the coil turns at the top of it to short them out. Shorting 6-1/2 turns minimized the SWR. I removed these turns, cut off the excess poly tubing, and resoldered the end of the coil to the cap. After confirming that the SWR remained low (nearly 1:1 at 145 MHz), I covered the completed antenna with heatshrink tubing.

Ideally, the bolt and nut should be brass for corrosion resistance, easy soldering, and good conductivity. Brass 3/8-24 hardware is difficult to find, but zinc-plated steel will work if



soldered carefully with a good flux. However, it may rust. Do *not* use cadmium-plated hardware — it may produce *highly toxic* cadmium fumes when heated.

Polyethylene has good dielectric properties and low rf loss; some other types of plastic do not. Many hardware stores carry polyethylene tubing (recognized by its stiffness and milky appearance). You can test questionable material for rf loss by placing it in a microwave oven beside of a cup of water (to act as a load); the material should not be hot after one minute of exposure.

Soldering wire to the copper fittings without melting the tubing is tricky. Work quickly: tin the fittings before assembly, and use a high-wattage iron.

My antenna mount extends about 1 inch above its bracket, adding an inch to the electrical length of the antenna. If your mount is different, you may need to experiment with the number of coil turns.

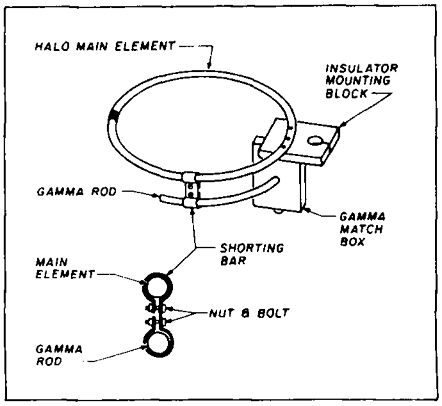
This antenna meets all my needs for local communications. It covers the entire band with less than 2:1 SWR, and with 25 watts I have no trouble working repeaters 20 miles away. Best of all, I can leave it on my van.

Gary Myers, K9CZB

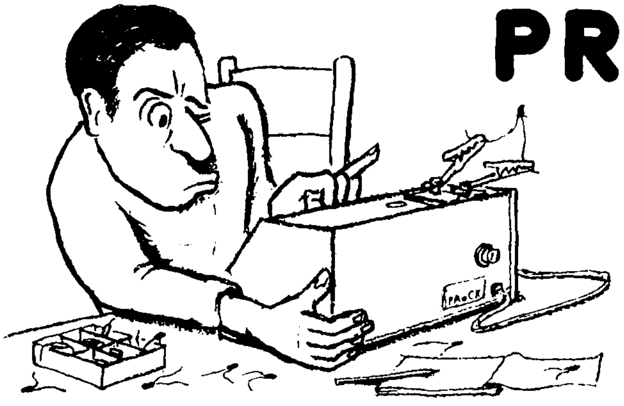
short circuit

2-meter halo antenna

Figure 3 of N6RA's May 1987 article, "A 2-Meter Halo Antenna," should show a wire going from the center pin of the SO-239 to the rotor plate of the gamma match capacitor. Also note that the halo's main element and gamma rod were bent around a large pot to form them in the circular shape. The illustration below shows



the halo and gamma rod in clearer detail than the original **fig. 3**.



PRACTICALLY SPEAKING

Joe Carr, K4IPV

feedback

Feedback is a necessary component of control systems, quality amplifiers, and other circuits. It is also important for magazine writers and publishers. That's why I publish my address each month, encourage people to make comments about what I've said (positive and negative), ask questions, and make suggestions for future columns. In at least one instance I wrote a reply to a reader question, and then edited and expanded it to become a column.

In June 1987 we discussed time domain reflectometry (TDR) — a measurement method in which an oscilloscope and pulse (or square wave) generator are connected in parallel with each other across the input end of a transmission line (**fig. 1**). By analyzing the interference of forward and reflected waves we can deduce much about the transmission line and its load. The article included oscilloscope photos of waveforms associated with various resistive loads.

This month we will discuss some points you readers felt I overlooked in my June 1987 column. For those of you who may have missed it, I will briefly reiterate some of the basics of TDR measurements.

review of TDR

Figure 1 shows the basic setup for TDR testing of transmission lines. You need a moderately wideband scope. Because square waves (or pulses) in the 10-kHz to 3-MHz range are used, the vertical bandwidth should be at least 15 MHz. This enables fast leading and trailing pulse edges to be reproduced with only slight degradation. Adjust the pulse width (or square wave period) to permit the reflected pulse to return to the source while the pulse is still high. Accordingly, adjust the signal generator output to approximate the length of the line. I have found it best to adjust the period/duration to permit the reflection to hit the waveform close to the center of the pulse.

A reader asks, "How does one determine the length of the transmission line from the TDR display?" **Figure 2** shows a pulse as displayed on the oscilloscope when the line is matched to the load. The pulse width is 0.9 μs. Because the connectors on the end of the line represent an impedance discontinuity, there is a small reflected signal which shows up on the display as a "pip" on the top of the pulse. A matched load, with the discontinuity, is easier to measure than a mismatched load, because the point at which the discontinuity occurs is easier to see.

In a test setup I used 100 feet (30.5 meters) of RG-58/CU cable connected to the load box described in my June 1987 article. The square-wave generator was adjusted to produce a waveform with a period of 1.8 μs, so the high portion was one-half that amount, or 0.9 μs. The cable I used had a polyethylene (not foam) dielectric, and according to standard wisdom, has a velocity factor of 0.66. Test results found the "pip" at 0.3 μs, which means that a round trip took 0.3 μs. Calculate the length of the cable using the formula below:

$$LENGTH = \frac{c\ V\ T_d}{2} \qquad (1)$$

Where:

LENGTH is the length in meters

c is the speed of light (3×10^8 m/s)

V is the velocity factor

T_d is the round-trip time measured on the oscilloscope

Using our example:

$$LENGTH = \frac{c\ V\ T_d}{2} \qquad (2)$$

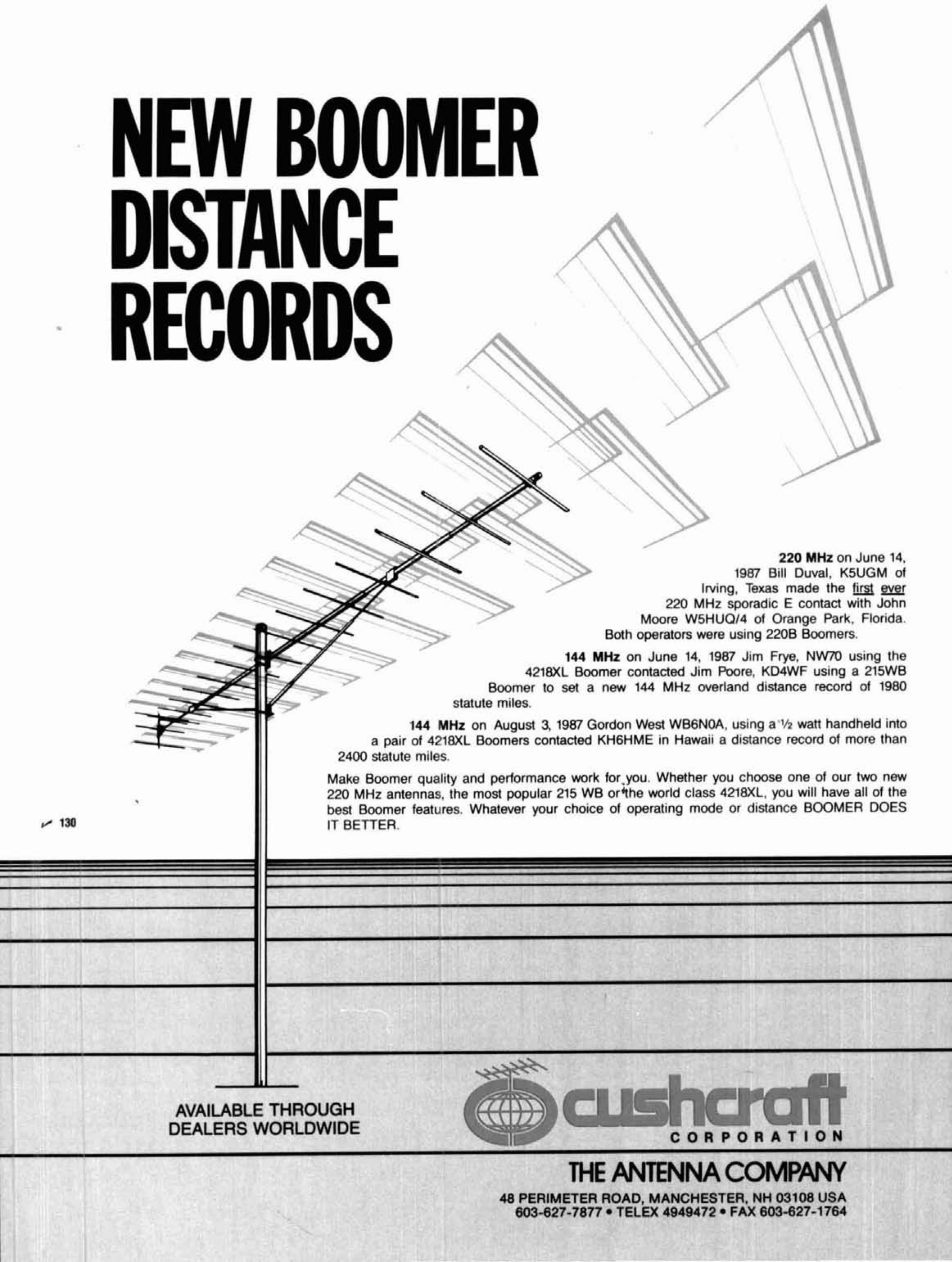
$$LENGTH = 29.7,\ or \qquad (3)$$

$$\frac{(3 \times 10^8\ m/s)\ (0.66)\ (3 \times 10^{-7}\ sec)}{2}$$

Within experimental accuracy (measurement of both the length of the coax and the return time) this result agrees closely with the actual physical situation. We can also measure the velocity factor of a particular sample of transmission line using the TDR approach. Rearrange the same equation to solve for V:

$$V = \frac{2 \times LENGTH}{c\ T_d} \qquad (4)$$

Which is calculated at 0.66.



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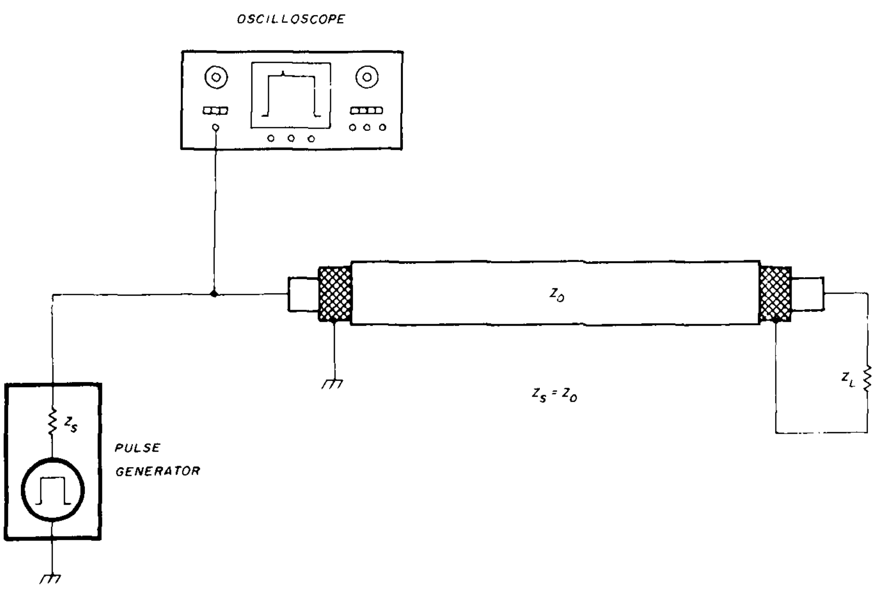

fig. 1. Time Domain Reflectometry (TDR) test set-up.

another sawtooth generator

In several columns we discussed the Poor Man's Spectrum Analyzer project. I offered a digitally derived sawtooth generator circuit to replace the original one. In response to the column I received a circuit from Isak Nowik (SM0NHS) in Stockholm. The simple circuit in **fig. 3** is based on the 555 timer IC. The basic circuit is the monostable multivibrator configuration of the 555, in which one of the timing resistors is replaced with a transistor operated as a current source (Q_1). You can use almost any audio small signal NP silicon replacement transistor, although for this test I substituted a Radio Shack replacement for the 2N3906 device (sold in packs of 15). The zener diode specified by SM0NHS was 4.3 Vdc, but I used a 5.6 Vdc unit that happened to be on hand and it worked well. Note that the output is taken from pins 6-7, rather than the regular chip output, pin no. 3.

Looking at **fig. 4**, you can see that the sawtooth wave is a lot more linear than the original sawtooth available from the spectrum analyzer sweep board. The period of the sawtooth is set by capacitor C_3 in **fig. 3**. SM0NHS recommended 100 to 500 pf, which is fine for some purposes, but for the slow speeds needed in the spectrum analyzer I found that increasing the value to 0.01 provided a better tradeoff. The value is not critical for circuit operation, so experiment with it to meet your particular timing requirements.

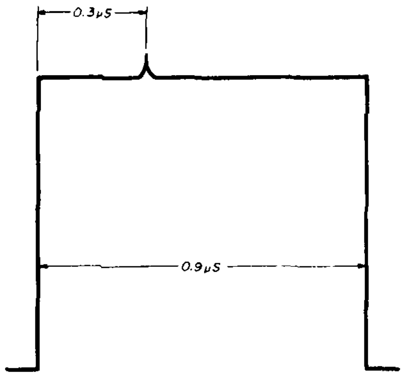

fig. 2. Oscilloscope display for TDR test. "Pip" is caused by the interference of forward and reflected signals.

The circuit as shown is a one-shot multivibrator. Triggering occurs in the 555 when pin no. 2 is within 66 percent of the supply voltage. When a pulse is applied to pin 2 through differentiating network R_1 C_1, the device will trigger because the negative-going slope meets the triggering criteria. To make an astable sawtooth multivibrator, drive the input of this circuit with either a square wave or pulse train that produces at least one pulse for each required sawtooth. Because the circuit of **fig. 3** is a non-retriggerable monostable multivibrator it will ignore subsequent trigger pulses during the one-shot's "refractory" period.

transmission line stubs

Transmission line sections can be used for impedance matching in antenna systems and other applications. In microwave circuits, transmission line segments are commonly used to match system impedances (e.g., 50 ohms) to device impedances. A quarter-wavelength transmission line has an interesting property. The impedance "looking-into" the line is equal to:

$$Z = \frac{[Z_0]^2}{Z_L} \tag{5}$$

Where:

Z is the driving point (or input) impedance

Z_0 is the characteristic impedance of the line

Z_L is the load impedance

By forcing the characteristic impedance to a specific value we can force the input impedance to match the source impedance. For example, when we have a source impedance Z_s (such as the output impedance of a transmitter), we can rearrange the equation above to find the characteristic impedance the quarter-wave transmission line requires to effect the match:

$$Z_0 = [Z_2 Z_L]^{1/2} \tag{6}$$

In many applications the usefulness of this fact is limited by the available standard transmission line impedances. But in UHF and microwave work we can design pc transmission lines that have any practical impedance. We can also design custom parallel transmission lines for hf and VHF antennas.

Another application of the line, a shorted quarter-wavelength transmis-

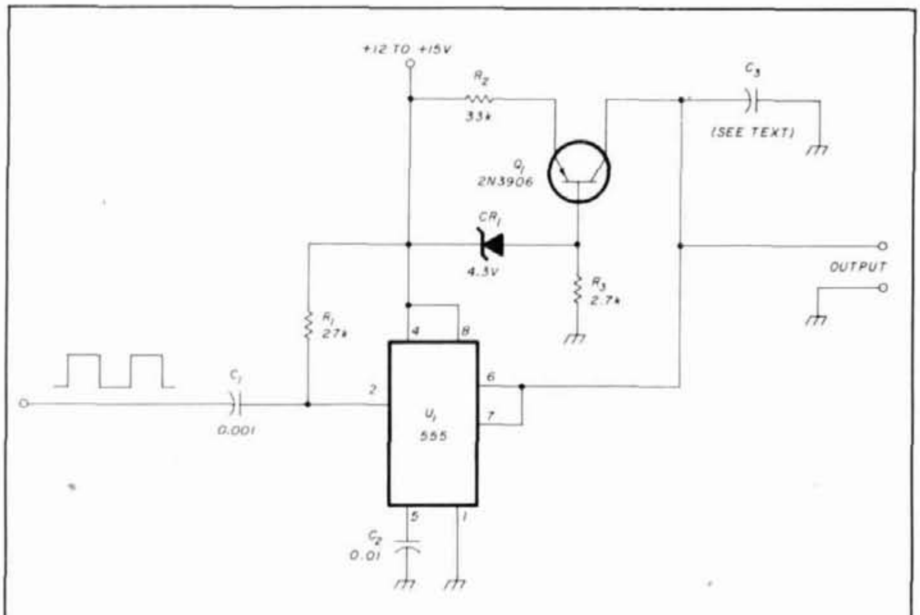

fig. 3. Linear sawtooth generator based on 555 IC timer.

sion line, offers an infinite impedance across the input terminals, but also a phase reversal of the signal. Because of this, shorted quarter-wavelength stubs are sometimes used in VHF antenna projects. One point some Amateurs miss, is that shorted stubs of other lengths can be used to produce almost any practical value of reactance. The impedance of a random length of transmission line is found from:

$Z = jZ_0 TAN(2\pi f Z_0 CL)$

Where:

Z is the impedance looking into the shorted line

Z_0 is the characteristic impedance of the line

f is the frequency in hertz

C is the capacitance per unit length in farads

L is the length in meters

This equation's usefulness is apparent when matching antennas that are reactive. Most Amateur Radio literature tells us to add some capacitance to match an inductive antenna, and vice versa. This is merely a restatement of the fact that the match of a complex impedance (to make it resistive) is the complex conjugate of the impedance. For example, if we have an impedance of 50 − j30 ohms, we can match it with a network that looks like 50 + j30 ohms. The reactive components cancel each other, leaving the impedance resistive.

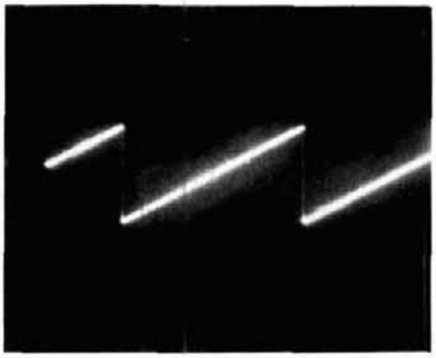

fig. 4. Sawtooth output from circuit of fig. 3.

The equation above contains a "j-operator" telling us that the answer is reactive; a "−j" says it is capacitive reactance, while a "+j" says it is inductive. Thus, a shorted matching stub, with a length designed to cancel out the reactance, can be placed at an antenna feedpoint in lieu of an inductor-capacitor matching network.

Joe Carr, K4IPV, can be contacted at POB 1099, Falls Church, Virginia 22041. Reader comments, inquiries, and recommendations are welcomed.

ham radio

Yagi vs. Quad: part 1

Development of the quad model

Few controversies in Amateur radio have sparked as much interest as the debate over which is the better antenna: a Yagi or a quad. Comparing models of both antennas at 440 MHz suggested that for a given boom length, the quad antenna holds about a 2-dB advantage.[1] However, this advantage does not seem to hold for quads on lower frequencies.[2]

This article approaches the Yagi vs. quad controversy from a different perspective, that of computer models. While a computer-generated antenna design is a step or two away from the real thing, it allows for greater manipulation of antenna geometry and a reproducible means of measuring antenna gain which is difficult to achieve in a real-life situation. Both Yagi and quad antennas may be "tuned" to maximize a specific parameter — for instance, maximum forward gain. Thus a Yagi and a quad may be compared for a given boom length and tuned for maximum forward gain, without worrying about compromising gain performance due to tuning for front/back discrimination or bandwidth.

An efficient means of analyzing quad antennas has not, to my knowledge, been developed. Although quads may be analyzed using general analysis programs such as NEC and MININEC (see Appendix for brief description of these programs) they require enormous amounts of computer time. A NEC modeling of a four-element quad with 40 match points per element requires computing and inverting a 1600-element complex matrix, not an easy job for a Macintosh. By accepting some simplifying assumptions we can develop a means of analysis similar to that successfully used for Yagi antennas.[3,4] The three needed parameters are: an estimate of element self-impedance (both real and imaginary), the mutual impedance between elements, and the field pattern of the quad loop.

In Part 1 of this article we will develop a means of estimating these parameters and examining the two-element quad. In Part 2, various quad configurations will be altered to maximize forward gain for a given boom length, and the calculated maximized forward gain will be compared to that found for similarly manipulated Yagi antennas. The following three sections deal with the estimation of the quad model. Skip to the "two-element quad" paragraph if you wish to avoid technical aspects not essential for an understanding of this series.

estimation of self-impedance

I originally tried to use MININEC, a general analysis

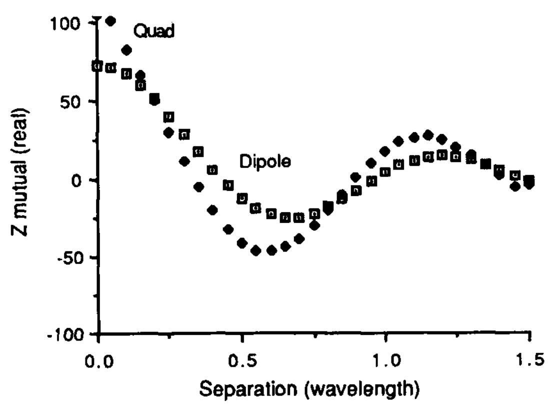

fig. 1. Real value of mutual impedance between 1.05 wavelength quad loops and 0.5 wavelength dipole elements as a function of separation. Note the similarity in the trajectories and the large magnitude of the quad values. This suggests that quad loops are at least as well coupled as Yagi elements.

By Dave Donnelly, K2SS, 8 Alder Street, Lincoln Park, New Jersey 07035

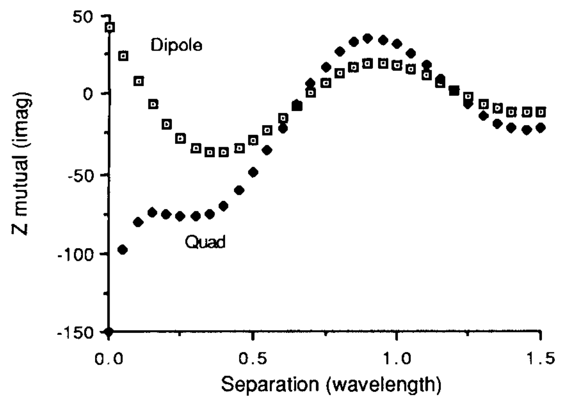

fig. 2. Reactive values of mutual impedance between 1.05 wavelength quad loops and 0.5 wavelength dipole elements as a function of separation.

program, to estimate the self-impedance of a quad loop. I started breaking a single 1-wavelength quad loop into 16, 40, 80, and 160 segments and examined the computed pattern and driving point impedance. While the loop gain and pattern were constant as the number of segments increased, the estimate of self-impedance did not converge on a single value. This poor convergence was worse as the quad element wire got thinner. Compounding this, the computer results showed that a 1-wavelength loop was shorter than resonant. In contrast Lawson had predicted, using different assumptions, that the zero reactance point on a quad loop should be close to one physical wavelength.[5] Why the discrepancy?

Rather than rely on computed values, I decided to measure the impedance. I bought four Fiberglas™ spreaders, strung out a 1-wavelength loop of No. 14 stranded wire at 14.1 MHz, and moved the loop up and down an 80-foot tower while measuring the drive impedance with a Delta Electronics OIB-2 impedance bridge. I measured the drive impedance between 14.0 and 14.3 MHz, and at several different heights. Assuming that the presence of the tower and coupling of the bridge to the element (or element to ground) did not affect the measured value, I estimated the drive impedance from measured values as: $R = 381 \cdot L - 277$ (R = real component) and X (reactive or imaginary component) $= 2330 \cdot L - 2452$, where L is the element length in wavelengths. A 1 wavelength loop measured 104 − j152 ohms, which is close to that calculated by MININEC using 80 match points (108 − j162).

mutual impedance

The calculated values for impedance using MININEC were found to be stable for larger wire diameters (1-inch diameter wire at 14 MHz). Mutual impedance was calculated by constructing two identical 1.04-wavelength loops (1-inch diameter wire), separated by 0.05 wavelength and calculating mutual impedance from the induced current in the second loop due to current in the first loop:

$$Z_{12} = \frac{V_1 - I_1 Z_{11}}{I_2} \quad \textbf{(1)}$$

where V_1 is the voltage applied to the first loop, I_1 is the current in the first loop, I_2 is the current induced in the second loop and Z_{11} is the self-impedance of the first loop. The real and imaginary parts are plotted in **figs. 1** and **2**, with similar values computed for half-wavelength dipoles shown as a comparison. As you can see, the magnitude of mutual impedance (or coupling) between quad elements stays quite large as the elements are separated. This suggests that the old adage that quad elements are a "Low q" circuit and hence are poorly coupled is *wrong!*

pattern

The quad field pattern computed by MININEC was stable as the number of segments increased and could be trusted for an accurate field description. The field pattern was translated into spherical coordinates and used for subsequent pattern and gain computation. A 1-wavelength loop showed 3.01 dBi gain compared with 2.18 dBi for a dipole. This gain for a square quad is consistent with that calculated using different methods.[5] These estimates of self- and mutual impedances for quad loops allowed the computation of the mutual impedance matrix. The currents flowing at the center of each element are determined by inversion of this matrix and multiplication by the driving voltage at each element. The pattern and gain can now be calculated from these currents.[6] As in reference 6, it is assumed that the mutual impedance and single element pattern are independent of element

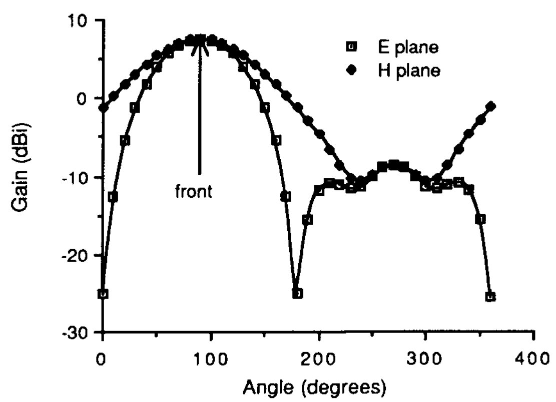

fig. 3. Free space pattern of 2-element quad with reflector = 1.050 wavelength, driven element = 1.021 wavelength and spacing = 0.15 wavelength. Note good front/back of about 20 dB.

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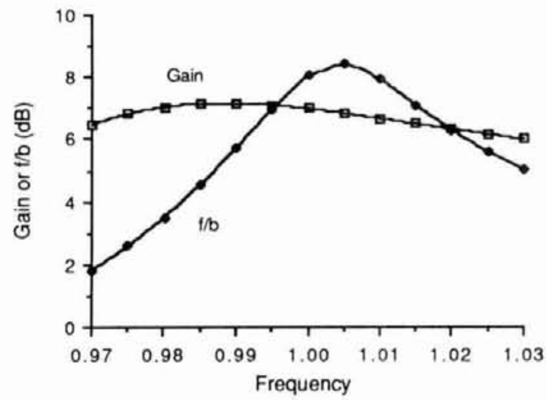

fig. 4. Free space forward gain and front/back as a function of frequency for a 2-element quad with reflector = 1.050 wavelength, driven element = 1.021 wavelength and spacing = 0.15 wavelength. Front/back values are divided by 2 hence vertical scale for front/back should be 0-20 dB. The 2-element quad retains good gain over a 4 percent change in frequency.

length. Although this is not exactly true, it is hoped that the "not true" part is minor. Since this assumption works for Yagi antennas it should also work for quads.

two-element quad

The dimensions for a two-element quad were taken from the *ARRL 1986 Handbook*: REF = 1006/Freq and Driven element = 999/Freq. Once again, I was skeptical of the computer model since my calculation of self-impedance indicated that this ARRL reflector was shorter than resonant. (I always believed that reflector elements should be longer than resonant.) However, computer results indicated that this antenna worked well. Forward gain with a spacing of 0.15 wavelength was 7.5 dBi and front/back was 17 dB, straight off the back (**fig. 3**). Bandwidth was sufficient to cover both the phone and CW segment if constructed for any band between 10 and 40 meters (**fig. 4**). The forward gain as a function of element separation indicated a maximum forward gain occurring at 0.15 wavelength (**fig. 5**). Increasing the reflector length to 1.040 wavelength while keeping the spacing constant at 0.15 wavelength could increase forward gain to 8.0 dB, but also caused a low of front/back to 10.6 dB.

conclusions

The results suggest several conclusions: (1) The gain of a single quad loop is 3.0 dBi compared with 2.16 dB for a dipole. (2) Coupling between quad elements is at least as good as Yagi elements, but the reactive value is quite different from dipole elements — staying negative until elements are separated by 0.7 wavelength. (3) Despite having a reflector which is actually shorter than resonant, a two-element quad from the

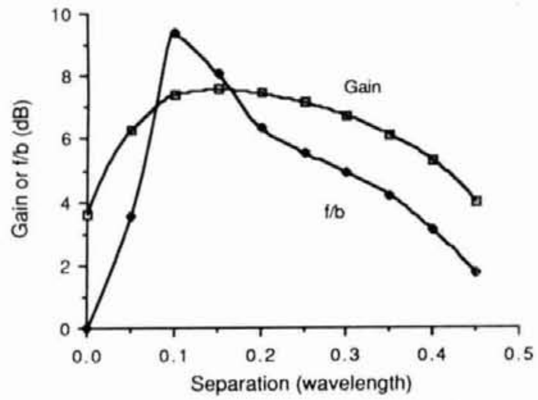

fig. 5. Free space forward gain as a function of element separation for a 2-element quad. Reflector = 1.050 wavelength and driven element = 1.021 wavelength. Front/back values are divided by two.

Antenna Handbook has good pattern and gain comparable to a two-or-three element monoband Yagi on the same length boom, but the gain is less than that for an optimum spaced three-element Yagi.[6]

In the next part we will calculate the performance of larger quads, examine the improvement that may be expected when gain is optimized, and compare calculated forward gains with similarly computed gains from Yagi antennas.

appendix

The single quad loop field pattern and two-loop mutual impedance values were estimated using MININEC, a general analysis program for thin wire antennas written by Alfredo Julian and colleagues at the Naval Ocean System Center. This program uses the method of moments for obtaining the current distribution along any antenna. Basically, the antenna is broken into many small pieces, the current is assumed constant along any given piece, and the wave equations are simultaneously solved to give a current distribution. The accuracy of the solution depends on breaking the antenna up into enough small pieces so that the calculated current distribution is smooth and approximates the real thing.

The MININEC program used here was slightly modified: it was translated from the original BASIC language into PASCAL and the matrices were expanded to allow for more match points.

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ham radio

a shortened 40-meter four-element
sloping dipole array

Instant azimuth change by switching characteristics of each element

Here's how to build a four-element sloper system for 40 meters on a small city lot using the same mast that supports your triband Yagi.

One of the best low-angle radiators for the lower bands is a *vertical dipole*. It concentrates the radiation at low angles and lessens dependence on a radial system, often a problem in vertical arrays. The radials are not as necessary as are verticals that have their maximum current at ground level.

Though the dipole in this array may not be exactly vertical, the signal is vertically polarized with a low angle of radiation. To get both directivity and gain, space several elements around a single support and use a switching network to select one dipole as the driven element. At the same time, lengthen the other dipoles electrically to act as reflectors. Add a 3/8-wavelength stub to make the dipole, which is self-resonant at the operating frequency, perform like a reflector. This stub looks inductive to the antenna and decreases its resonant frequency by about 5 percent. Select one of the sloping dipoles through the switching network to electrically rotate the antenna pattern.

We live on a small city lot, and our tower with a five-element tribander at the top is a rather fragile one guyed to resist strong winds. At first it seemed impossible to use any slopers because of potential interaction with the guy wires. The problem was solved by replacing the metallic wires with strong nylon rope. Good UV-resistant nylon ropes are available in yachting shops. (Do *not* use ropes designed for mountain climbing!) Four dipoles, spaced 90 degrees apart, are run along the nylon rope. Usually a tower has only three guys, separated by 120 degrees. Three elements are probably just as effective, as observations of the incoming signals show that the forward lobe is *rather broad.**

shortened elements

The tower is about 56 feet high, and two of the four guys are fastened to the house about 6 feet above ground — a serious problem. Consequently, with the maximum possible element length, shortened dipoles had to be used. My design, shown in **fig. 1**, uses a 4.5 μH inductance in each leg. A coil, 12.5 turns, 1.5 inches in diameter and 1.4 inches long, provides the value of inductance.

Tuning of each shortened dipole is critical. They were tuned in a horizontal position about 13 feet above ground. As each antenna was put on the tower, the resonant frequency changed. I spent quite some time tuning the elements for resonance by connecting one element through an SWR bridge to the transmitter while the other elements were disconnected. Though not grounded, they must be there with the required open feedline as there is always some interaction between the elements. Each element has to be tuned for the same resonant frequency and must show the same SWR across the band in order to switch direction without retuning the transmitter or linear. **Figure 2** shows a plot of SWR for one of the elements. The resonance is in the CW portion of the band. To tune for a higher frequency, just shorten the antenna.

*Using a similar array for 80 meter, Fuller, W2LU, comes to the same conclusion. See reference 2.

By Jurgen A. Weigl, OE5CWL, Karntnerstr. 212/59, A-8053 Graz, Austria

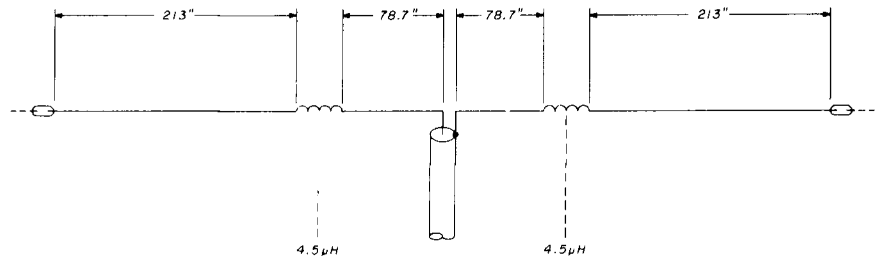

fig. 1. Shortened 40m element lengths and loading coil locations.

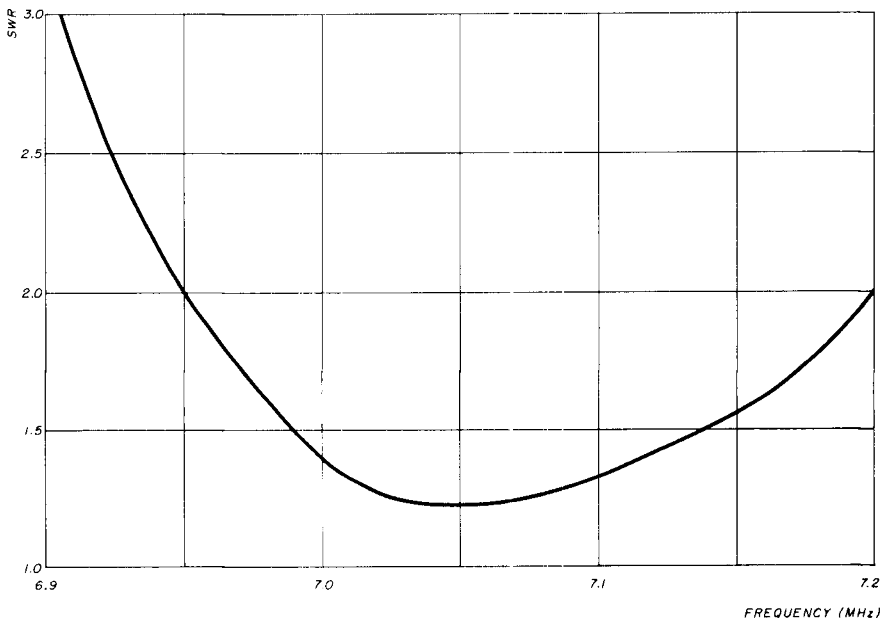

fig. 2. Shortened 40m dipole SWR versus frequency. Antenna was tuned for lowest SWR over the European segment of the band. Note the SWR is less than 2.0:1 over 200 kHz of bandwidth.

attaching the dipoles to guy lines

The antenna should be attached to the guy at only three points. The guy line passes through the tube of the upper loading coil, through a small loop fastened to the center insulator, and then through the tube of the lower loading coil. The upper end of the antenna is suspended from a 20-inch rope. Be sure the antenna moves along the guy freely or it may break in strong winds.

controlling the direction

Figure 3 shows the basic antenna layout. The feedlines (3/8 wavelength long), which connect the various elements to the control box, are a vital part of the system. Remember that you have to consider the velocity factor of your coax cable. **Equation 1** gives you the physical length for cutting your feedlines.

$$\ell = 0.375\ \lambda K \qquad \textbf{(1)}$$

where λ = wavelength

K = velocity factor

For RG-8 or RG-58 coax, K is about 0.66 so λ is 36 feet. You can determine the velocity factor for other cables from antenna handbooks. Do not use inexpensive TV coax since no reliable velocity factor value is available. The feedline from the control box to the transmitter may be any length but should be the same type of cable as the stubs. **Figure 4** is a schematic of the control box. For the four-element array, three relays are required to select the proper feedline. (If you use only three elements, you need only two relays.) The contacts should be rated for about 6 to 10 amps

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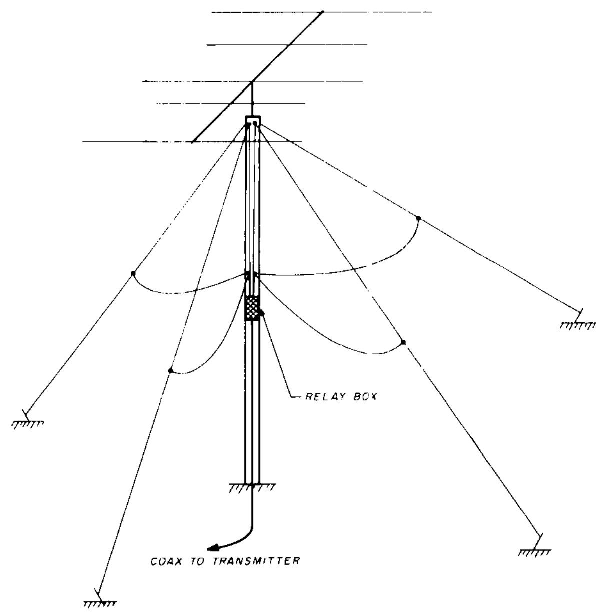

fig. 3. Four element sloping dipole array with tribander atop the tower. Each coaxial line from element to relay box is 36 feet long!

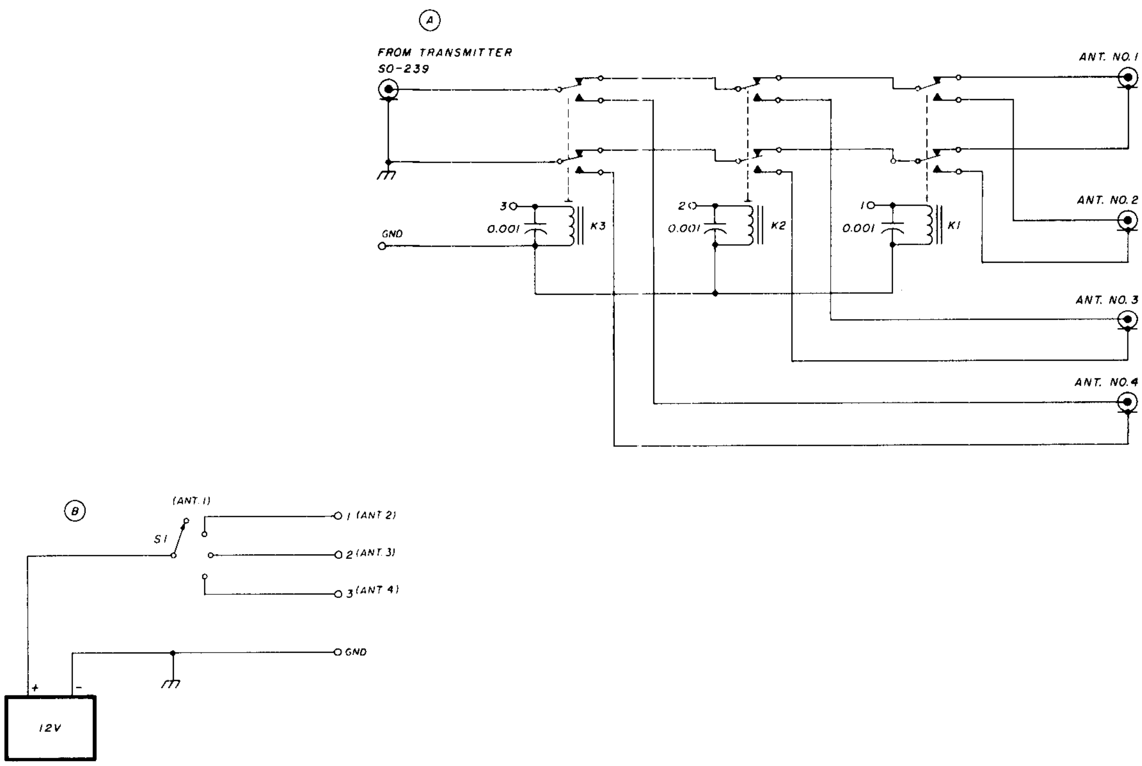

fig. 4. Switching network for the four element sloper array. (A) Tower mounted relay box circuit (a modification of a diagram that appeared in the ARRL 1974 Antenna Handbook) (B) Control unit in ham shack.

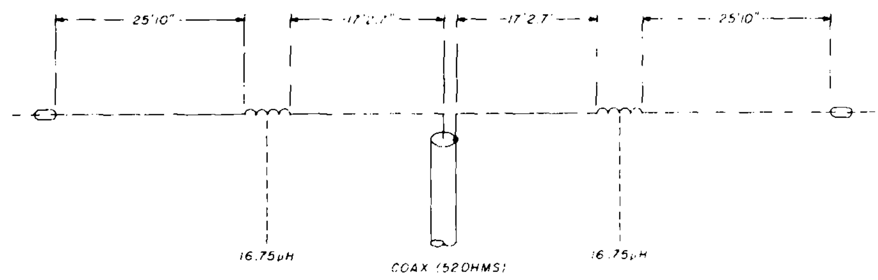

fig. 5. Shortened 80m dipole, overall length 26.1 meters, approximately 86 feet.

and contact spacing should be good for at least 200 volts. This handles up to 800 watts at low SWR. *Never* switch the direction when power is applied to one of the elements — hot switching may result in damage. Because the feedlines of the unused elements are not grounded, the braid of the coax is open circuited when not in use. This is the only way to achieve the proper tuning that allows the elements to act as reflectors.

other bands

I hope this article will encourage you to build this or a similar array. If space permits, use full-size elements. If a shortened dipole is needed, design data is available for other frequencies.[1] An 80-meter dipole for use at 3.8 MHz is described in **fig. 5**. With an antenna tower only 78 feet high you will be able to join other Amateurs with a directive 80-meter antenna. This bandwidth is small but if you use low-loss coils the antenna should be quite effective and possibly achieve 4 dB of gain.

references

1. *The ARRL Antenna Book*, Newington, Connecticut 06111, 1974.
2. Fuller, Eugene B., W2LU, "Sloping 80 meter Array," *ham radio*, May 1979, page 70.

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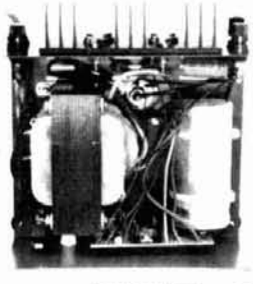

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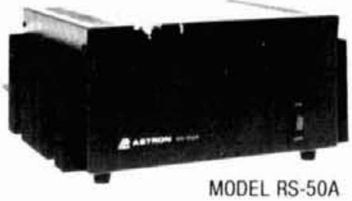

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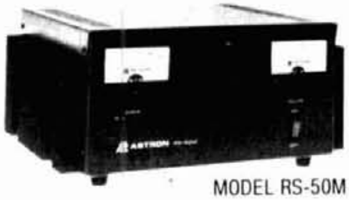

MODEL RS-50M

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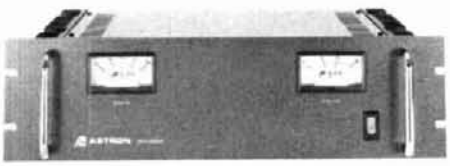

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RS-5A	4	5	3½ × 6⅛ × 7¼	7
RS-7A	5	7	3¾ × 6½ × 9	9
RS-7B	5	7	4 × 7½ × 10¾	10
RS-10A	7.5	10	4 × 7½ × 10¾	11
RS-12A	9	12	4½ × 8 × 9	13
RS-12B	9	12	4 × 7½ × 10¾	13
RS-20A	16	20	5 × 9 × 10½	18
RS-35A	25	35	5 × 11 × 11	27
RS-50A	37	50	6 × 13¾ × 11	46

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RS-50M	37	50	6 × 13¾ × 11	46

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VS-20M	16	9	4	20	5 × 9 × 10½	20
VS-35M	25	15	7	35	5 × 11 × 11	29
VS-50M	37	22	10	50	6 × 13¾ × 11	46
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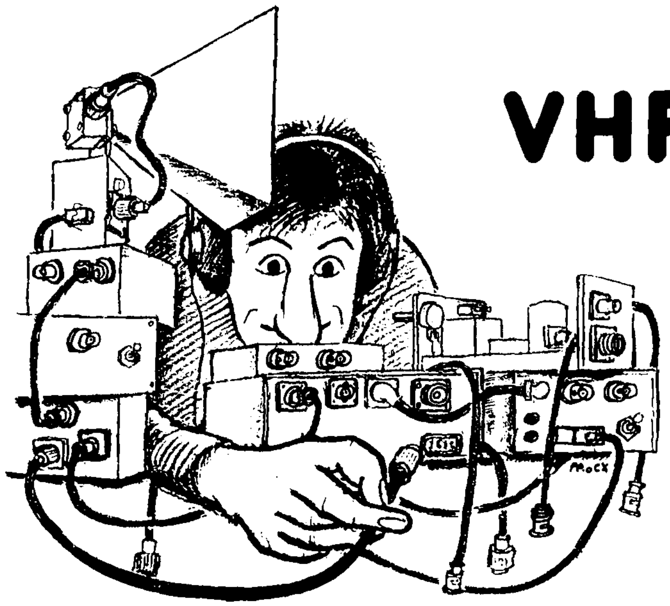
RS-10S	7.5	10	4 × 7½ × 10¾	12
RS-12S	9	12	4½ × 8 × 9	13
RS-20S	16	20	5 × 9 × 10½	18

*ICS—Intermittent Communication Service (50% Duty Cycle 5min. on 5 min. off)



VHF/UHF WORLD

Joe Reisert, W1JR

power splitters and summers

VHF/UHF World has discussed optimum antennas[1,2] high gain antennas[3], and how to obtain additional gain using multiple or "stacked" antennas in an "array".[4,5] At VHF and the lower UHF bands I have often recommended using the longest possible Yagi with a clean pattern.[4] If the antennas do not have the desired gain, an alternative is to stack similar antennas.[4,5]

Stacking usually requires phasing lines and power splitter(s) or summer(s) — Amateurs call them power dividers. Several have appeared in this column, but I still get letters asking how they work, how to design them, and what types I recommend.[5,6]

This month I will discuss various types of power dividers, their advantages and disadvantages and specific electrical and mechanical examples. After reading this column you should be able to either duplicate the designs or build your own.

why use a power divider?

As **references 4** and **5** point out, the first step in antenna selection is to choose the desired gain. Second, select an antenna design that fits your physical requirements. Remember that if the type you choose is a collinear or Yagi, even the largest one may not have the necessary gain. A practical alternative is to "array" or "stack" several of them to reach the gain you want.

Stacking standard or extended/expanded collinears was common practice until the late 1970s.[7] Most collinears use open wire or twin lead transmission lines that are often paralleled to form the power divider function. At the final feedpoint, an impedance matching network or tuning "stub" (and possibly a balun) are used to match the transmission line to the antenna.

With the Yagi, it's common practice to stack antennas one above the other, side by side, or in combinations of both (see **references 4** and **5**). Open wire lines are recommended for stacking, especially on EME, but for reliable all-weather performance they should be configured as described in **reference 5** to maintain a low VSWR.

Nowadays when you want high gain, it is common practice to stack several of the newer high performance Yagis in an array. Since most Yagis have a feedpoint impedance of 50 ohms unbalanced, the use of coaxial power dividers is a natural. Just build up a set of identical phasing lines, connect them to a suitable coaxial power divider, and you're ready to go.

power divider fundamentals

From this point on I will describe only coaxial power dividers — by far the most common types. For more on open-wire line read **references 5** and **7**.

The six most important power divider properties are: impedance, number

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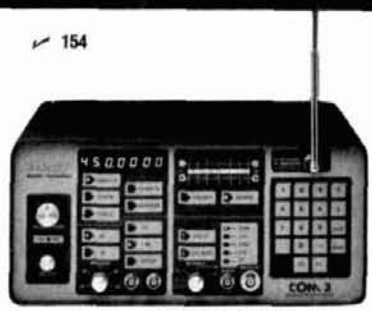

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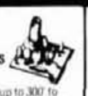

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Table 1. Some of the common properties of coaxial power dividers as descibed in the text.

parameter	most common	other common possibilities
Input/output impedance	50 ohms	12.5 to 100 ohms
Number of outputs	2 and 4	6 and 8
Power level at output	-3 and-6 dB	-8 and -9 dB
Phase between outputs	0 degrees	90 and 180
Isolation between outputs	none	>20 dBs typical
Insertion loss	negligible	0.1-0.5 dB typical

of output ports, power level at each output port, phase of each output port, isolation between outputs (if applicable), and insertion loss as shown on **table 1**. Did I miss anything?

Power dividers can be designed for virtually any impedance. If only coaxial phasing lines are used, impedance matching is greatly simplified by using 50 ohm input and output impedances. This greatly reduces the complexity of the phasing lines and the overall array.

Power dividers can theoretically be designed with any number of outputs. The most common types used by Amateurs are symmetrical 2 and 4 way although 6- and 8-way types are sometimes used. The greater the number of outputs, the more difficult it is to impedance match between the input and the output ports and the greater the mechanical complexity. In addition, 8-way power dividers require longer phasing lines which have loss and tend to be counter productive.

In a lossless equal output power divider, the output at each port is a function of the division ratio. For instance, in a two-way divider, the output power will be one-half the input level or minus 3 dB. In a four-way divider the output will be one-fourth the input or minus 6 dB, and so on.

The phase of a power divider's outputs is a function of the design. Amateurs usually prefer the outputs for stacking antennas to all be the same phase, simplifying the phasing line design.

Ninety degree or quadrature phasing may be preferable when antennas are used in circularly polarized arrays. The most common 90 degree power dividers are the two-way quarter wavelength types using hybrid couplers described in last month's column.[8]

The coaxial power dividers favored by Amateurs are sometimes called "reactive" power dividers as shown in **fig. 1A**. They perform best when all the outputs are well matched in impedance and phase. More on these later.

Another widely used power divider is the isolated type shown in **fig. 1B**. It consists of two transmission lines with an extra port or junction, which absorbs any mismatches on the outputs, and is often referred to as the "Wilkenson" type after its inventor.[9] These power dividers are usually found in low power applications like local oscillator power splitters in transceivers.[6]

The Wilkenson power divider's problem is that it requires an external "floating" load, R_1 in **fig. 1B**, typically 100 ohms in the two-way types. These resistors must have very low reactance and the ability to absorb at least 50 percent of the available input power. A 2-way Wilkenson power divider operating at maximum Amateur power levels would require a 100 ohm 750 watt resistor — not your common everyday flea market item! You can understand why they're not very popular in high power applications.

The loss in power dividers is important, especially in high power applications and high performance antenna arrays. The reactive type in **fig. 1A** has inherently low loss, particularly if the impedance transformer is made from an air (dielectric) line. The Wilkenson type in **fig. 1B** usually has a small loss because of the construction and the isolation load.

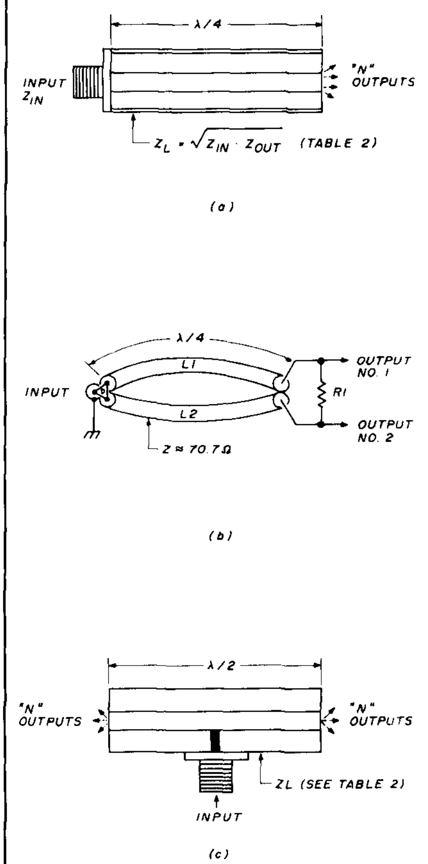

fig. 1. This figure shows the three most common types of power dividers used by Amateurs: (A) The reactive quarter wave impedance transformer type where the impedance is the geometric mean betwen the input and output as explained in the text and as shown in Table 2. (B) The Wilkenson isolated power divider uses two quarter-wavelength transformers. The impedance of L_1 and L_2 are 70.7 ohms and R_1 is 100 ohm for the 2-way version.[9] (C) The "so called" half wavelength power divider is really two quarter-wavelength types connected back-to-back as described in the text.

power divider design

We will concentrate solely on the reactive power divider type shown in **fig. 1A**. The principal of operation is best described as an impedance transformer. At hf, this could be an "L" network but at VHF and UHF it usually consists of a quarter wavelength of transmission line.

The transmission line impedance is the geometric mean impedance between the input and output loads as shown in the equation below:

$$Z_I = \sqrt{Z_{IN} Z_{OUT}} \qquad (1)$$

Where Z_1 is the impedance of the transmission line, Z_{in} is the input impedance, and Z_{out} is the impedance with all the outputs in parallel. For example, in a 50 ohm 2-way power divider design, the output load will be 25 ohms (two 50 ohm lines in parallel) making the required line impedance of the quarter wavelength transformer 35.36 ohms. If a 4-way design is used, the output load will be 12.5 ohms and require a 25 ohm quarter wave line section.

Other power division ratios are also possible (see **table 2**). However, the impedance of the matching transformer of a quarter-wave power divider can get very low, especially when four or more outputs are required. Also, the mechanical problems of co-locating more than four output connectors are formidable, especially on the higher frequencies.

For these and other reasons, two quarter-wave transformers are often connected back-to-back as shown in **fig. 1C**. This is often referred to as a "half-wave power divider"; in reality it is still a quarter-wave type. **Table 2** shows that not only is the impedance of the transformer higher, but the length is twice as long so the phasing lines can be shortened somewhat, decreasing system losses.

The half-wave power divider works on the same principle as the quarter-wave type, but this time the inputs as well as the outputs are in parallel. For instance, if two 4-way quarter-wave types were connected back-to-back, the input impedance would become 25 ohms. To keep a constant 50-ohm impedance throughout, each impedance transformer must transform its outputs to 100 ohms. Thus, when the two transformers are connected in parallel at the input port, the impedance is 50 ohms.

The half-wave power divider has several other properties. In the 2-way type, the impedance of the line is approximately 71 ohms and two standard 70-75 ohm coaxial transmission lines can be used. The 4-way type is even simpler because the impedance of the matching transformer is 50 ohms throughout! (See **table 2**.)

Table 2. The impedance of the transmission line used in common quarter and half wavelength power dividers using 50 ohm input and output impedances.

number of outputs	quarter wavelength	half wavelength
2	35.36	70.71
3	28.87	NA
4	25.00	50
6	20.41	40.82
8	17.68	35.36

simple coaxial power dividers

One of the simplest and lowest-cost power dividers you can build for 6 and 2 meters is the half-wave type using quarter wavelength pieces of standard coaxial cable and "Tee" connectors. I developed them for a commercial antenna company and have used them for almost ten years on my 2-meter EME array. It is relatively small and very flexible, with good VSWR and negligible insertion loss.

Construction details are shown in **fig. 2**. In the 2-way type, the transmission lines are standard RG 11A/U or equivalent coax cable. The 4 way uses standard RG 8A/U, RG 213A/U, or equivalent. Because the dielectric velocity factor of the coax is 66 percent and the coaxial Tee fittings have some finite length and a different dielectric, the lines are shorter than expected in the 2-meter version. Equivalent models can surely be used at higher frequencies, but you may have to experiment with the length of the lines to fully compensate for all the connectors.

A few words are in order on the connectors used for these low cost power dividers. Low cost PL 259s and UHF Tee connectors are usable but not advisable as they are difficult to weatherproof. I recommend weatherproof "N" connectors like the UG21 series and the UG-28A/U Tee connector.

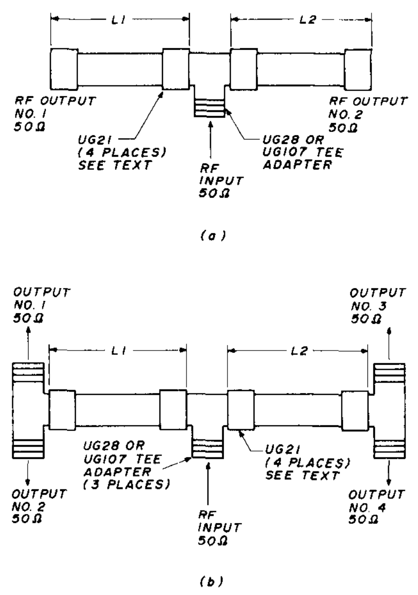

fig. 2. This is an example of simple power dividers made from ordinary coax cable and coaxial adapters. L_1 and L_2 are 58 and 12 1/2 inches long for 50 and 144 MHz, respectively. See text for other frequencies. (A) This is a 2-way power divider. L_1 and L_2 are made from 50 ohm coax such as RG 8 A/U or RG 213 A/U.

air dielectric power divider construction

In the early 1970s I used copper and brass tubing to make 2-way quarter-wave and 4-way half-wave power dividers. Because they are essentially air dielectric coax, they exhibit very low loss.

To design an air dielectric power divider, first choose the proper transformer impedance from **table 2**. Determine the desired inside diameter of the outer tubing and the outside diameter of the inner tubing (or rod) using the standard equation for a coaxial transmission line as follows:

$$Z_0 = 138 \log b/a \qquad (2)$$

Where Z_0 is the impedance of the line,

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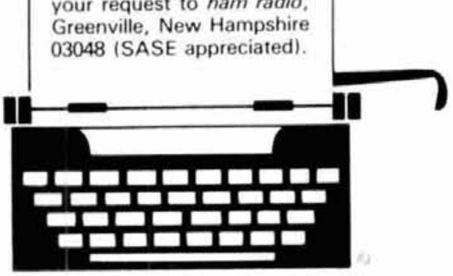

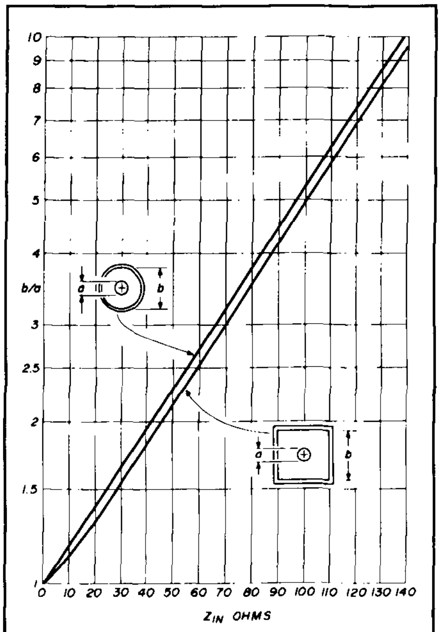

fig. 3. This chart can be used to determine the impedance of an air dielectric coax transmission line made from either round or square outer conductor.

"b" is the inner diameter of the outer tubing and "a" is the outer diameter of the inner line, both in the same units. To simplify calculations, I prepared the graph in **fig. 3** which shows various ratios and their corresponding impedances.

For example, in a 4-way half-wave power divider, the impedance of the line should be 50 ohms (per **table 2**). From the graph or **eqn. 2**, the b/a ratio of the tubing chosen should be approximately 2.3. This can be constructed from brass tubing 9/16 inch inside diameter (5/8 inch outside diameter) and an inner tubing with an outside diameter of approximately 1/4 inch. Although this is an impedance of 48.6 ohms, its maximum VSWR is 1.03:1.

A typical 432-MHz power divider of the type just described is shown in **fig. 4**. It uses brass tubing available at hobby shops or from "Small Parts, Inc."*. It can be adapted for any frequency by changing the distance between the connectors for a quarter wavelength with the following formula:

$L = 2950/f$ **(3)**

* Small Parts, Inc., P.O. Box 381736, Miami, Florida 33238

Where L is a quarter wavelength in inches, and f is frequency in MHz. At 144 and 220 MHz a quarter wavelength would be 20.5 and 13.4 inches, respectively.

I discussed some of the complexities of this divider's construction with Dick Turrin, W2IMU. He fabricated a 432 MHz 2-way power divider using standard type-L copper water pipe, 1/2 inch copper pipe "T" fittings, and a pipe coupling he got from a plumbing supply house.

For the inner conductor he used the copper center conductor from an old defunct 7/8 inch rigid coaxial air line that got contaminated with water, but 5/16 inch brass or copper tubing should be close enough. Details on his 432 MHz 2-way power divider are shown in **fig. 5**.

I recommend this power divider design because it has very low VSWR and insertion loss. Again, the lengths can be adjusted for any frequency with **eqn. 3**. It should also be easy to convert it to a half-wave 4-way type similar to **fig. 4** by placing a pipe "T" at the center junction and using an appropriate center conductor.

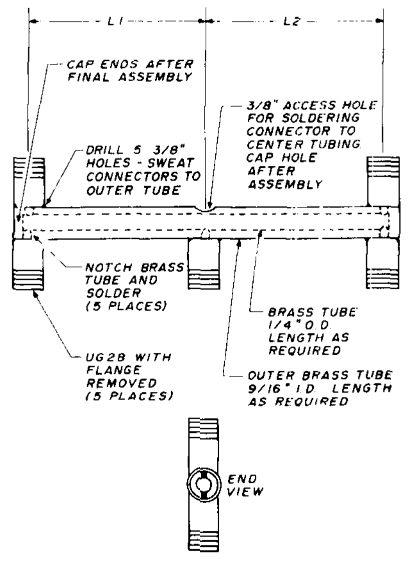

fig. 4. This is an example of a 4-way power divider made from hobby shop or equivalent brass or copper tubing. L_1 and L_2 are 20.5, 13.4, and 6.83 inches for 144, 220, and 432 MHz, respectively.

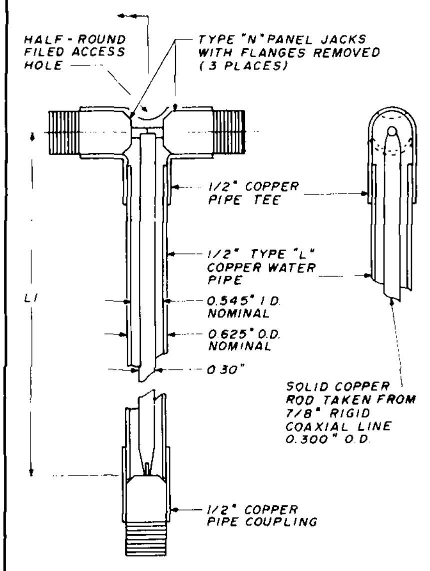

fig. 5. This is an example of a 2-way "plumbers delight" power divider designed by W2IMU. Length L_1 is the same as in fig. 4.

My favorite power divider construction technique uses 1 by 1 inch square tubing with thin (1/16 inch) walls. Some have used thick wall (1/8 inch) tubing but when I tried it, my tap broke through the walls.[10]

Many have avoided constructions with square coaxial transmission line because there have been many conflicting formulas published in Amateur literature. The true formula is found in **reference 11** but is complex and difficult to use. A simple, accurate formula for impedances between 30 and 140 ohms follows:

$Z_0 = 138 \log ((b/a) \cdot 1.08)$ **(4)**

Where Z_0 is the impedance of the line in ohms, "b" is the inside width and "a" is the diameter of the center tubing in the same units. For example, if you use standard 1 by 1 inch square aluminum tubing, it has an inside dimension of 0.875 inches. When used with a center conductor of 13/32 inches outside diameter, you obtain an impedance of 50.6 ohms, close enough for a 4-way half-wave power divider. A graph of this function appears in **fig. 3** using the more accurate formulas from **reference 11**.

A typical 432 MHz 4-way power divider using square outer tubing is shown in **fig. 6**. It uses standard UG 58 type N coax connectors with hobby shop brass for the inner conductor. All connectors are attached by drilling and tapping 4-40 holes in the tubing.

Start by drilling all the connector holes. (I use a Greenlee punch.) Next, drill and tap the connector mounting holes. Don't forget to make a few small "weep" holes on the bottom side of the power divider near the connectors to let moisture escape. Then remove all burrs or metal filings.

If your center conductor material is too short, you can join hobby shop brass by soldering a short piece (2 inches) of the next smaller diameter tubing inside. You can drill a few small diameter holes in the center tubing where the connectors are attached. Inserting a short piece of No. 14 copper wire aid solder flow to the center pins of the connectors. Finally, seal the ends of the tubing. I prefer to use two layers of 1-inch wide metallic tape which can be removed for periodic checks.

The power divider in **fig. 6** can be redesigned as a 2 way by changing the inner tubing diameter to 9/32 inches. I designed and built a 6-way power divider for 2 meter EME using a 15/32 inch inner tubing diameter with 20.5 inch spacing between connectors. You can use other division numbers by changing the transformer impedance per **table 2**. Similarly, spacing the connectors a quarter wavelength (using **eqn. 3**) will effect a frequency change.

The half wave power divider in **fig. 6** can be converted to a quarter wavelength power divider by removing one side of the divider and using the impedance recommended in **table 2**. A 1296-MHz version is shown in **fig. 7**. It uses most of the mechanical details of the half wave type in **fig. 6**.

some unique power dividers

So far, I have described ordinary quarter and half wavelength power dividers. There are several other techniques or variations also worth mentioning.

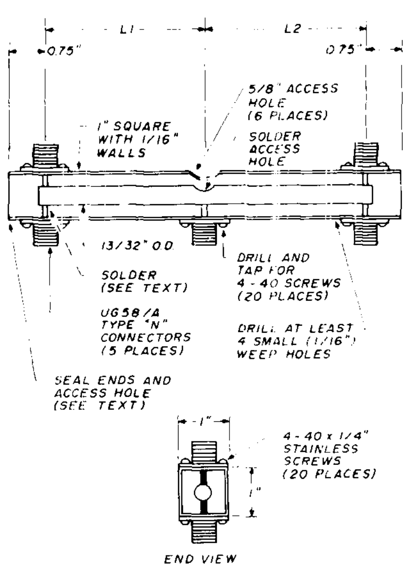

fig. 6. Half wave power divider using square tubing for the outer conductor. The lengths of L_1 and L_2 are the same as in *fig. 4*.

Although we have concentrated on 50 ohm input and output impedances, there is no reason why a power divider can't be made with different input and /or output values if you choose the proper transformer impedance. For example, antennas could be fed with low loss 75-ohm cable like the CATV type and connected to a 75-ohm output impedance power divider that matches to a 50-ohm transmission line or vice versa. Obviously a 75-ohm input and output impedance is also acceptable if the transformer is modified using **eqn. 1**.

Most power dividers, especially the air dielectric type, will also operate normally at their third harmonic with low VSWR. As mentioned earlier, this will probably allow the phasing lines to be shortened. One possiblity is to use a 144-MHz power divider at 432 MHz. If the tolerances and fabrication are accurate enough, a 432-MHz power divider will operate at 1296 MHz. Other versions are described in **reference 12**.

Several years ago Cliff Schaible, W2CCY, devised a unique 432-MHz power divider composed entirely of standard type N coaxial fittings and adapters (**fig. 8**).[13] These adapters are expensive if purchased new but are reasonably priced and abound at Amateur flea markets. If you have the fittings in your junk box, the whole assembly won't take more than five minutes to construct. The measured VSWR is very acceptable — about 1.1:1.

Reed Fisher, W2CQH, later developed a similar but simpler 4-way power divider for the 23-cm (1296 MHz) band.[14] made up of three type N Tee connectors as shown in **fig. 8B**. Note that the outer adapters are UG 107 A/U, an older and slightly longer version of the more common UG 107 B/U. If you can't find the "A" version, a "B" version can be substituted with slightly higher VSWR.

build or buy your own power divider?

Building a power divider is not difficult if you have access to the necessary materials. As I mentioned earlier, metal parts are available at most hobby shops or through Small Parts, Inc. At least two Amateurs offer parts or kits of parts for power dividers,

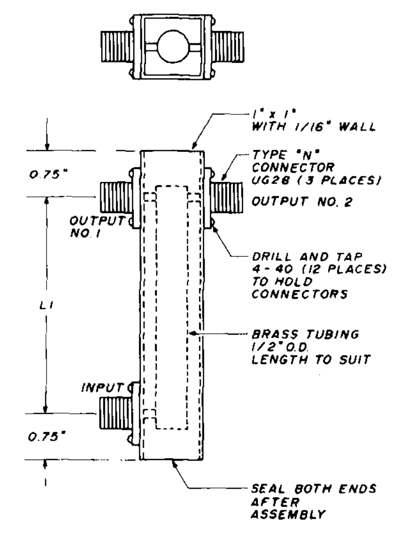

fig. 7. 2-way quarter-wavelength power divider using square tubing. L_1 is 2 1/4 inches for 1296 MHz. For other frequencies see *fig. 4*. Construction follows the same scheme shown in *fig. 6*.

Tom Rutland, K3IPW*, and Charley Byers, K3IWK.**

Most antenna manufacturers offer suitable power dividers. If you prefer to purchase a finished product, check through the advertising section of this and other Amateur publications. Whichever way you choose to go, power dividers should no longer be a mystery.

evaluating your power divider

As we have discusssed, 2- or 4-way power dividers are common in Amateur arrays. The half-wave power dividers, especially the 2- and 4-way types, are preferred because they allow the use of shorter phasing lines.

Although I don't have concrete information to support it, my feeling is that the higher the mismatch at the output end of a power divider, the more likely that array performance will be degraded because the antenna sees a big mismatch when looking into the power divider. In this regard, the 8-way half-wave or the 4-way quarter-wave types are less desirable.

After building or purchasing a power divider, test it before installing it in the antenna system. An easy method for testing power dividers at low power levels is described in **reference 15.**

First, place a good low-VSWR termination at all power divider output terminals. Next, measure the power divider input VSWR (it should be 1.2:1 or better) and remove one of the terminations. The VSWR should increase. If not, something is wrong with the impedance transformer.

When installing the power divider in the antenna array, mount all the antennas at their final locations with phasing lines in place. For optimum performance the length of the phasing lines should be odd-multiples of a quarter wavelength (see **reference 5**).

Continue by testing each antenna separately. The VSWR should be low, preferably 1.2:1 or better. Then connect all the antennas to the power divider and retest the array VSWR. Don't worry if VSWR increases a bit because the individual antennas may each have a different impedance. Furthermore, there are usually mutual impedance affects in stacked arrays.

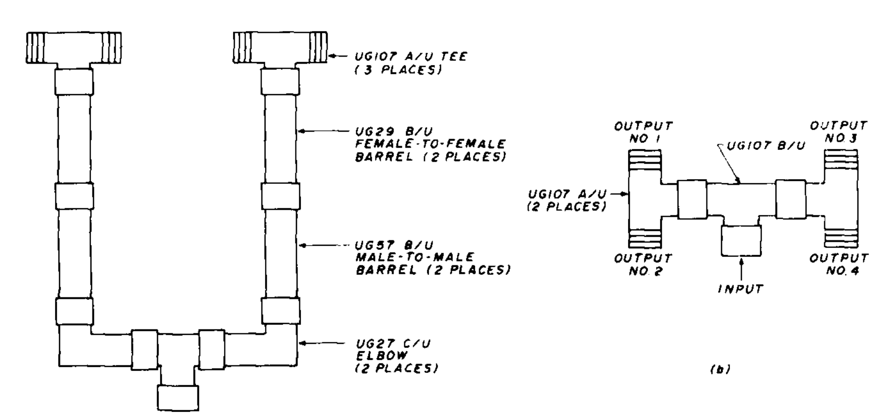

fig. 8. Power divider made completely from coaxial adapters: (A) 4-way for 432 MHz, (B) 4-way for 1296 MHz. See text for further information on the adapters.

summary

This month we discussed different power dividers with emphasis on the more common types Amateurs use. Other power divider configurations are possible and the formulas, graphs, and construction techniques described above should help you design models that meet your needs.

Did I miss any important points? If so, please let me know and we'll discuss them. After all, this is your column!

acknowledgements

I would like to thank Dick Turrin, W2IMU, for letting me publish his "plumbers delight" power divider shown in **fig. 5.**

new records

This has been a record month for new VHF/UHF records. In last month's column I mentioned a new 6-meter EME record. It didn't last very long. On January 5, 1988, Ray Rector, WA4NJP (EM84DG), extended his own EME record on 50.005 MHz to 4470 miles (7193 km) by working Mike Staal, K6MYC/KH6 (BK29AO). Ray was using his same 4 Yagi array and Mike was running a quad array of 10-element 50 foot long Yagis. Both stations were running the legal power level.

On October 18, 1987 at 1945 UTC, the EME contest expedition to the NRAO Greenbank, West Virginia radio telescope set a new 13-cm (2304 MHz) EME record. As W3IWI/8 (FM08CK), they had a 2-way QSO with John Shorland, ZL2AQE (RE78JS), Wellington, New Zealand. The record shattering distance is 8658 miles (13,931 km). W3IWI/8 was using a 150-foot (!) dish and 100 watts while ZL2AQE had a 12-foot dish and 18 watts.

On January 29, 1988, Jay Liebmann, K5JL (EM15DQ), and Gary McCormick, WA5ETV (EM15EM), had what is reported to be the first ever 2-way 33-cm (902 MHz) EME QSO. The distance was approximately 13 miles (21 km). Jay used a 28-foot dish and 150 watts while Gary used a 30-1/2 foot dish and 200 watts. I'll bet this record won't last long!

I'm sorry about the improper listing of the 47-GHz record in February 1988 *ham radio*. I forgot to update the table to include the 13.9 mile (22.4 km) record of WA3RMX/7 and WB7UNU/7 reported in the September 1987 issue. My apologies to Tom and Lyn.

Congratulations to all the new record holders. These are exciting times and it is good to see that the records can always be extended. Keep it up!

* Rutland Arrays, 1703 Warren Street, New Cumberland, Pennsylvania 17070

** Byers Chassis, 5120 Harmony Grove Road, Dover, Pennsylvania 17315

important VHF/UHF events:

April 29-May 1	*Dayton HamVention*
May 4	*Predicted peak of the Eta Aquarids meteor shower at 1900 UTC*
May 6	*ARRL 902 MHz Spring Sprint Contest (Friday evening local)*
May 10	*EME perigee*
May 12	*ARRL 1296 MHz Spring Sprint Contest (Thursday evening local)*
May 15	*New moon*
May 20-22	*14th Annual Eastern VHF/UHF Conference, Nashua, New Hampshire (contact W1EJ)*
May 21-22	*ARRL 50 MHz Spring Sprint Contest (Saturday evening local)*
May 26	*ARRL 2304 MHz Spring Sprint Contest (Thursday evening local)*
June 4	*EME perigee*
June 7	*Predicted peak of the daytime Arietids meteor shower at 0150 UTC*
June 9	*Predicted peak of the Zeta Perseids meteor shower 1020 UTC*
June 11-13	*ARRL June VHF QSO Party*
June 14	*New moon*
June 21	*± 1 month. Peak of mid-latitude Sporadic E propagation.*

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by Doug DeMaw W1FB

The thrill of working a rare one using a QRP radio is hard to explain. It can even be more thrilling if the radio is unsophisticated and homebrewed. The QRP Handbook stays away from heavy technical discussions and formulas and gives you in a plain, easy-to-read format all the essentials you need to build your own QRP gear. Six chapters cover: The essentials of receiving, the world of QRP transmitters, QRP accessory gear, QRP transceiving, the QRP workshop and QRP operating. An appendix gives suggested books, magazine articles and parts suppliers. © 1986 86 pages 1st Edition

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REFERENCE

YOUR GATEWAY TO PACKET RADIO
by Stan Horzepa, WA1LOU

Here is the complete beginner's guide to Packet Radio written by ARRL Packet expert, WA1LOU. Beginners will find the complete easy-to-understand explanations eliminate many of the frustrating aspects of packet operation. Full of helpful hints and tips that come from thousands of hours of on-the-air experience. Keep from re-inventing the wheel — learn from an expert. 208 pages © 1987.

AR-PKT Softbound $9.95

6th ARRL COMPUTER NETWORKING CONFERENCE
August 1987

Packet radio is growing at a phenomenal rate. This collection of papers given in August 1987 at Redondo Beach, represents the "cutting edge" of packet technology. 29 papers cover every subject from equipment design and improvement and digital signaling processing, to the latest techniques in data transfer. Add this book to your collection of earlier Computer Network Conference — be 100% up-to-date and packet compatible. © 1987

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KA-DPII (MS-DOS Computers) $49.95

THE PACKET RADIO HANDBOOK
by Jonathan Mayo, KR3T

Packet radio is the fastest growing mode in Amateur operation today. No wonder — it combines the power of today's microcomputer with worldwide digital communications. Newcomers will find this book to be full of helpful tips, tricks and information that will help get them on Packet as quickly as possible. Providing you first with packet basics, this book progresses through the inner workings and operational aspects of packet to a look at future technology still in developmental stages. Also includes: using bulletin boards, traffic handling on packet, modulation methods and networking principles, protocols (both AX.25 and VADCG) and a thorough discussion of the various TNCs and accessories available. © 1987 1st Edition 218 pages.

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DX FORECASTER

Garth Stonehocker, KØRYW

1987 propagation summary

It wasn't until May 1987 that the necessary 12 months of sunspot data were available to determine when the actual 11-year solar cycle minimum had occurred. A fairly rapid and sustained *increase* thereafter tentatively confirmed September 1986 (SSN-12.3) as the sunspot *minimum* month. Similar data defined June 1986 (flux = 67.6) as the solar cycle *flux* minimum. In light of these two mimima, 1987 can be considered the first year of solar cycle 22.

During 1987 the *sunspot number* increased from 17.4 to about 50 while the *solar flux* increased from 72.5 to 100. Using the superimposed epoch method it is apparent that these increases are comparable to the early rise of cycle 21. This indicates that the new cycle is right on target.

Little solar activity was evident during January, February, and March. Therefore no solar flare-related sudden ionospheric absorption (SID, ultraviolet, and x-ray radiation) occurrences were reported. The geomagnetic field was also quiet during this time (which is normal for the winter season) except for two periods, February 20th-22nd and March 27th. The resulting disturbances were related to coronal transparency and its resulting solar wind particle increase. Midlatitude noontime maximum usable frequencies, MUFs, were around 16 MHz. Solar activity increased in April, and from then through May the level of the geomagnetic disturbances decreased in step with increased solar flux radiation pressure against the earth's magnetosphere. The only reported Sudden Ionospheric Disturbance (SID) was on May 25th. However, the geomagnetic field came alive with a long series of disturbances from May 23rd to June 20th, just as solar flux values were returning to a 27-day minimum. Midlatitude noontime MUFs decreased 27 percent during this period. High latitude and polar signals were also attenuated. The geomagnetic field was not really quiet again until November and December, and then only for a day at a time until December 24th. This is the usual annual scenario. SIDs were reported on July 24th, August 23rd, October 30th, November 6th and 27th, and December 26th. SIDs last only up to one hour or so at the subsolar point on the sunlit side of the earth.

Because of a flare, a medium size geomagnetic disturbance of short duration occurred on July 29th. From August 26th through the end of the year a sizable disturbance was reported every few days. This is unusual because the autumnal equinox is usually a quieter period than the springtime equinox. There were so many disturbances in September that the midlatitude noontime median MUF diminished from 18 to 11 MHz. The MUF decrease during these disturbances was about 8.75 percent of an A unit (geomagnetic index), which is *within the sunspot minimum relationship* discussed in *ham radio*, December 1985. More disturbances as well as visible aurora occurred on August 26th, September 11th and 25th, and November 23rd. These were solar flare-related and each caused a 10 to 15 percent MUF reduction at midlatitude at local noontime. The dozen other disturbances that occurred over this same time frame were due to coronal transparency or changes in the sun's magnetic field structure, which increased the solar wind particle speed and density. This period of increased solar activity and related disturbances was probably caused by rapid changes on the sun as it "heated up" for cycle 22. These disturbances are an indication of what to expect during cycle 22. The next two years will show increased activity, the following two a leveling off at a maximum and, after that, the start of a decreasing trend.

Propagation conditions during this active period will have their ups and downs. An increased number of openings with better signals on 6 and 10 meters are the pluses; lower daytime signal strengths on the lower bands and greater numbers of more intense geomagnetic disturbances causing periods of no high latitude and polar propagation are the minuses. The signal strength and direction variability may increase the possibility for openings to unusual DX locations, making ham radio more fun. Learn to use these minuses in your favor.

last-minute forecast

Expect very good openings on 10 to 30 meters during the second and third weeks of May. This is one of the last months to expect many or very good transequatorial openings before going into the summer season. The best time for these openings will be during medium sized geomagnetic disturbances.

MAY

WESTERN USA

GMT	2300	2200	2100	2000	1900	1800	1700	1600	1500	1400	1300	1200	1100	1000	0900	0800	0700	0600	0500	0400	0300	0200	0100	0000	
PDT	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	
ASIA FAR EAST	20	20	20	20	20	20	20	20	20	20	20	20	20	20*	15	15	15	15	20	20	20	20	20	20	N
EUROPE	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	15	15	15	NE
S. AFRICA	15	15	12	10	10	10	10	12	12	15	15	15	20	20	20	20	20	20	20	20	20	20	15	15	E
S. AMERICA	12	12	12	15	15	15	20	20	20	20	20	20	20	20	20	15	15	12	12	10	10	10	10	12	SE
ANTARCTICA	15	20*	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	20	20	20	20	20	20	20*	S
NEW ZEALAND	10	12	12	12	15	15	20	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	10	10	SW
OCEANIA AUSTRALIA	12	12	12	12	15	15	20	20	20	20	20	20	20	20	15	15	12	12	10	10	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	20	30	30	30	20	20	20	20	20	20	15	15	15	15	15	15	15	NW

MID USA

MDT	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	
ASIA FAR EAST	20	20*	15	15	15	15	20*	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	N
EUROPE	15	20*	20	20	20	20	20	20	20	20	20	20	30*	30	30	30	20	20	20	20	20	20*	15	15	NE
S. AFRICA	15	12	12	10	10	10	10	10	12	12	15	15	15	20	20	20	20	20	20	20	20	20	15	15	E
S. AMERICA	15	15	12	12	10	10	10	12	12	12	15	15	20	20	20	20	20	20	20	20	20	20	20*	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	10	12	12	12	15	15	20	20	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	10	SW
OCEANIA AUSTRALIA	10	10	12	12	15	15	20	20	20	20	20	20	20	20	20	15	15	15	12	12	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	20	30	30	30	20	20	20	20	20	20	15	15	15	15	15	15	15	NW
CDT	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	

EASTERN USA

EDT	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	7:00	6:00	5:00	4:00	3:00	2:00	1:00	12:00	11:00	10:00	9:00	8:00	
ASIA FAR EAST	20	20	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	N
EUROPE	20	20	20	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	20	20	20	20	20	20	NE
S. AFRICA	15	15	12	12	10	10	10	10	12	12	15	15	20*	20	20	20	20	20	20	20	20	20	15	15	E
CARIBBEAN S. AMERICA	15	15	12	12	10	10	10	12	12	15	15	15	20	20	20	20	20	20	20	20	20	20	20	15	SE
ANTARCTICA	20	20	20	20	20	20	20	20	20	30	30	30	30	30	30	30	30	30	30	20	20	20	20	20	S
NEW ZEALAND	10	10	12	12	15	15	20	20	20	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	SW
OCEANIA AUSTRALIA	10	10	12	12	15	15	20	20	20	20	20	20	20	20	20	15	15	12	12	12	10	10	10	10	W
JAPAN	20*	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	15	15	15	15	15	15	20*	NW

The italicized numbers signify the bands to try during the transition and early morning hours, while the standard type provides MUF during "normal" hours.

*Look at next **higher** band for possible openings.

These should occur around May 2nd, 11th, 17th, and 24-28th. Toward the end of the month sporadic E short skip openings will probably help higher band DX conditions a little. However, in this early stage of the E_s season the lower bands are expected to have more of these openings. The lower bands are also expected to be very good during the first and fourth weeks, except for local thunderstorm noise during spring storm passages. Enjoy the evenings on these bands, because in another month or so the summertime air mass thunderstorm noise will be upon those of us in the Northern Hemisphere.

The full moon, of interest to moonbounce DXers, occurs on the 1st and 31st of this month. An Aquarid meteor shower (for meteor-scatter and meteor-burst DXers) peaks between May 4th and 6th, with rates of 10 and 25 per hour for the northern and southern hemispheres, respectively. The lunar perigee is on the 10th.

band-by-band summary

Ten, twelve, fifteen, and twenty meters will support DX propagation from most areas of the world during daylight hours and into the evening, with long skip out to 2000 miles (3500 km) per hop. Signals on the upper three bands arrive mainly from the southern countries and occur near local noontime. Sporadic-E short skip will be available at local noon on some days toward the end of the month. The direction of propagation will follow the sun across the sky: morning to the east, south at midday, and west in the evening.

Thirty, forty, eighty, and one-sixty meters are the nighttime DXers' bands. Because of low solar flux early and late in the month, daytime DX — particularly in the early mornings — may be worthwhile on those days. The direction of propagation follows the darkness path across the sky: evening to the east, north and south around midnight, and toward the west in the predawn hours. Distances will generally decrease to 1000 miles (1600 km) for skip on these bands. Sporadic-E openings will be most frequently observed around sunrise and sunset toward the end of the month.

ham radio

product REVIEW

MFJ Model 931 artificial ground

Here's a gadget that's new (but it isn't) and just might be the answer to some problems you may be having. It certainly was a help to me.

I had just changed to one of the new, all digitally controlled hf transceivers. The rig was a dream until a full power linear was put on line. Suddenly there were instability problems in the new rig, even though the antenna was a fairly good match and had been installed for a number of years without incident.

My first attempt at fixing things involved going over the grounding system and improving about as much as I could in an old house that was not wired with Amateur Radio in mind. After doing this, I could use a bit more power before the problems would begin, but the station was still only running at about a quarter of its capability. Frustration was rampant.

Then I remembered a new MFJ product in the other room waiting for review. Called an artificial rf ground, it is basically a modified antenna tuner designed to make a short random length of wire look like a quarter-wave counterpoise. There are just two connections: one to a short wire from the transmitter ground, and the other to a random length of wire thrown on the floor.

The MFJ-931 includes an rf current sensor to help make tune-up a very quick process. Just adjust the tuning capacitor and the inductor tap switch to peak the current reading and you're in business. The whole package comes assembled in a neat metal enclosure that could very easily be mistaken for a modest sized antenna tuner. It should look right at home in the typical ham shack.

Needless to say, this artificial ground was all I needed. Installation took only a minute or so. The new rig immediately settled down and ran just as well as it had before the amplifier was turned on, and peace returned to the household. I do plan to work a bit more on my ground problem and try to eliminate the need for this extra crutch in my station. However, this product certainly gained my respect in the middle of a DX contest, and I will be glad to have it on hand until matters are under better control.

There should be no end to the number of other uses that one could make of this box. Field Day quickly comes to mind along with any other portable or temporary operation, particularly if higher power usage is anticipated. I'll bet that some TVI problems might even be lessened with this interesting little package. How about putting one at the TV set? The possibilities are endless.

I want to point out that using this product does not provide a dc ground for your station. You are still responsible for ensuring that your rig and antenna system are properly grounded for both operator safety and equipment protection. The instructions are clear on this point, and it is to their credit that the manufacturers have not overlooked this most important item. They have also correctly pointed out that at times the counterpoise itself might get rather hot with rf energy. Thus, care must be taken to insulate this lead to protect anyone who might accidently come in touch with it.

The concept of using an indoor quarter-wave counterpoise at the transmitter to act as an rf ground certainly is not new. But as far as I know, the idea of a tuning network specifically designed to accomplish this task easily over the whole Amateur hf spectrum *is* new. From my experience, MFJ-931 is worth consideration by anyone having problems in this area.

W1NLB

Circle #302 on Reader Service Card.

NEW products

NETWORK 1000 ringrotor

TIC General has introduced the NETWORK 1000 ringrotor antenna mount designed to convert your tower into the axis for networking. It rotates your antenna around rather than above the tower, making it possible to have multiple rotating antennas (with individual rotation ability) on a single tower.

Features include a steel gear drive with 24 VDC gear motor, I-beam ring construction, and positioning to 1 degree. They also manufacture a digital control box designed to work with the ringrotor.

For more information contact TIC General, PO Box 1, Thief River Falls, Minnesota 56701.

Circle #303 on Reader Service Card.

learn Morse Code with your pc

GGTE announces Morse Tutor©, Version 2.1, for learning the International Morse Code or improving code skills.

Morse Tutor is available for IBM PC, XT, AT and equivalents. The program features both Standard (uniform dits, dahs, and spaces) and "FARNSWORTH" (spaces lengthened relative to dits and dahs) methods.

The program introduces each of the letters, numbers, punctuation marks, and special combination characters in 11 lessons. Each lesson features a review of previous current ones, through random character and word drills. Lesson 12 provides random QSO practice of durations up to 10 minutes per QSO.

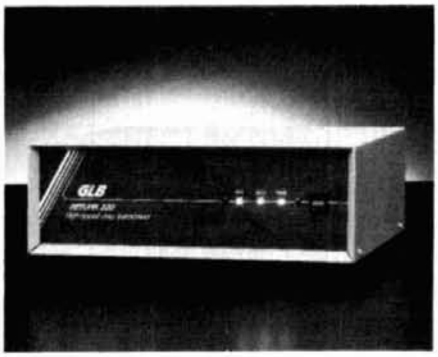
Character display can be selected to occur simultaneously with code sending or after the lesson. A self-calibration utility to control the clock speed of the computer ensures accurate code for speeds ranging from 1 to over 100 words per minute. Morse Tutor provides for setting the tone frequency over the full audible frequency range. All selectible variables — tone frequency, code speed, display mode, and calibration values — are remembered from session to session.

Morse Tutor is $19.95 plus $2.00 for shipping and handling (California residents please add $1.20 sales tax). Order from GGTE, 21881 Summer Circle, Dept. MTH, Huntington Beach, California 92646.

Circle #304 on Reader Service Card.

NETLINK high-speed data transceiver

GLB Electronics has announced a digital-in, digital-out data radio for high-speed packet linking. The NETLINK 220 features 220-225 MHz simplex operation, 2 watts of output and a data rate of 19,200 baud. It is adaptable for use with any node controller that generates and accepts



5-volt CMOS logic levels. It uses the FSK modulation method, requiring a 25-kHz receiver bandwidth at 19,200 baud. Operational temperature range is −30 to +60 degrees C.

NETLINK is compatible with most data formats, including NRZ and NRZI used in packet node controllers. No external clocks or synchronization are needed. Duplicate input-output paths are provided, so that either CMOS (0-5 volts) or RS-232-compatible (+ − 10 volt) signals can be used for data.

With the use of PIN diodes for antenna switching, turnaround time is 1 millisecond making it possible to use simplex operation at high data rates. To prevent interference through "key clicks", NETLINK uses time sequencing and shaping of the turn-on and turn-off envelopes.

Frequency drift is regulated by oven-controlled crystals and temperature compensated oscillator circuits. A frequency tracking system keeps the signal centered in the receiver passband. The frequency last received is "remembered" between packets; this feature avoids the need to acquire the signal on every transmission.

The receiver uses five large helical resonators for image and out-of-band rejection. A 1-millisecond squelch is available at the rear connector. NETLINK selects filters that achieve good adjacent channel performance with reasonably good phase linearity, and uses a phase correction filter for final waveform correction. Sensitivity is rated at 0.5 uv for a bit error rate of 10^{-3}. The ultimate error rate is better than 10^{-8}.

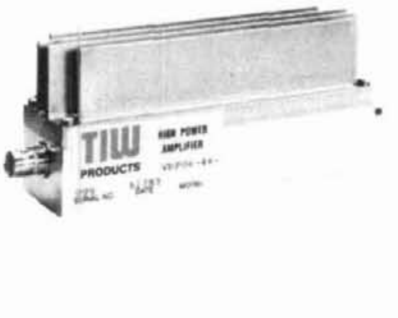
The transmitter is designed for continuous operation. Six poles of filtering keep adjacent channel interference at a low level. For unattended operation, NETLINK has a key-down timer set to 10 seconds with reset on key-up. Panel LEDs indicate transmitter keying, squelch, and power status. All data and control signals are brought to a DB-25S connector on the rear panel. Additional connections include transmit key, squelch, discriminator, tracking status, and tracking control. NETLINK operates on a 12-volt dc supply wired to an independent jack. The antenna connector is a BNC female. All input-output signals are RFI-filtered, and NETLINK complies with all applicable sections of part 15 of FCC rules. It also has passed tests to part 97 specifications.

The cabinet measures 12 x 10 x 4 inches and weighs 5 pounds, 8 ounces. The list price is $799, $699 Amateur net. For more information contact GLB Electronics, Inc., 151 Commerce Parkway, Buffalo, New York 14224.

Circle #305 on Reader Service Card.

high-power rf amplifier

TIW Systems has announced the addition of the VHP-06 to its existing line of high-power rf amplifiers. With a 40- to 400-MHz bandwidth, 1-watt continuous output, and 44-dB nominal gain (with up to 68-dB gain available by arrangement with the factory), the VHP-06 features a footprint of only 2 x 5 inches, this amplifier utilizes efficient thermal packaging that allows it to operate at 50 degrees C using only convection cooling.



The use of advanced solid-state hybrids allows the VHP-06 to amplify several combined signals while generating few intermodulation products, making this amplifier appropriate for CATV distribution networks, local area network repeater sites, and last-mile distribution of any video or broadband signal. The VHP-06 comes with 75-ohm input and output impedance and a choice of BNC, SMA or "F" type connectors. The amplifier is powered from a user-supplied +24 volt source and draws less than 480 milliamperes. Other impedances and gains may be obtained upon request.

Complete information on the Model VHP-06 is available from Rob Wellins at TIW Systems, Inc., 1284 Geneva Drive, Sunnyvale, California 94089.

Circle #306 on Reader Service Card.

large character environment for computers

Kidsview Software, Inc. has released Kidsview™ and Kidsword™ software transforming the Commodore 64 and 128 into a quadruple-sized character environment for visually impaired and special needs users. Kidsview quadruples character size while closely preserving normal computer operation. The entire contents of the "regular" screen are presented in original order so text continuity is maintained.

Kidsview may be used to write or run programs. Although some commercial software will run, it is intended primarily as a development and display tool.

Kidsword is a large character word processor designed for children, with features making it suitable for more advanced applications. The characters and background change color so that visually impaired users can adjust the screen for maximum comfort and clarity. Kidsword prints large, standard size characters and will be available for the Apple IIe soon. For more information contact Kidsview Software, Inc., P.O. Box 98, Warner, New Hampshire 03278.

Circle #307 on Reader Service Card.

new coaxial cable

Certified Quality RG8X is similar to the RG8X and mini 8 type of coaxial cable introduced by BERKTEK. It has a characteristic impedance of 50 ohms, a 78 percent velocity of propagation, and 95+ percent bare copper shielding over foamed polyethylene dielectric which covers a 16 AWG stranded bare copper center conductor. Its outer diameter is 0.242 inches. The outer jacket is PVC Class I.

Advantages are low cost, high flexibility, light weight, and half the signal loss of RG58 at about the same cost. Limitations are those associated with foamed polyethylene dielectric. It won't stand much heat from any source, and will absorb moisture if not well sealed. In 100 feet, losses at 10 meters are about 1 dB, at 2 meters about 3 dB.

Certified Quality RG8XIIA II has all the characteristics of CQRG8X plus a non-contaminating Class IIA PVC jacket for extended cable life.

Certified Quality 4XL 8 IIA is the latest addition to the "Poor Man's Hardline" class of coaxial cable. It has a non-contaminating Class IIA PVC jacket. Inside is 95 percent coverage tinned copper braid shielding over 100 percent aluminum polyester shield. Semi-solid polyethelene dielectric encloses a 9.5 AWG solid bare copper center conductor. Velocity of propagation is 84 percent, impedance is 50 ohms, and loss figures are about 1.6 dB at 2 meters, 3 dB at 450 MHz, and 4.2 dB at 900 MHz. This class of cable will not withstand constant movement; for some uses a more flexible jumper is indicated.

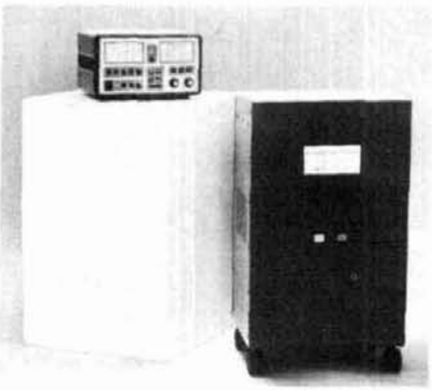
For further information contact "The Wireman", Certified Communications, Pittman Road, Route 2, Landrum, South Carolina 29356.

Circle #308 on Reader Service Card.

high-power linear amplifier

The 230A is a continuous duty linear covering all Amateur bands from 1.8 to 21 MHz (1.8-30 MHz for export). Tuning and protection are controlled by a microprocessor. There is a microcontroller for metering and an rf/power supply deck with remote location capability.

Features include two back-lighted LCD displays, drive power of 50-70 watts, and a built-in SWR computer LDC display readout. The 230A has heavy duty power components, automatic safety monitoring for reverse power, grid and plate current, air flow, filament voltage, and is in compliance with FCC regulations.



The commercial model 230C provides continuous frequency coverage from 1.8 through 30 MHz with a constant duty power output rating of 2250 watts PEP.

For more information contact Advanced Radio Devices, 103 Carpenter Drive, Sterling, Virginia 22170.

Circle #309 on Reader Service Card.

flea market

RATES Noncommercial ads 10¢ per word; commercial ads 60¢ per word **both payable in advance**. No cash discounts or agency commissions allowed.

HAMFESTS Sponsored by non-profit organizations receive one free Flea Market ad (subject to our editing) on a space available basis only. Repeat insertions of hamfest ads pay the non-commercial rate.

COPY No special layout or arrangements available. Material should be typewritten or clearly printed (**not** all capitals) and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** cannot check each advertiser and thus cannot be held responsible for claims made. Liability for correctness of material limited to corrected ad in next available issue.

DEADLINE 15th of second preceding month.

SEND MATERIAL TO: Flea Market, Ham Radio, Greenville, N. H. 03048.

TEST EQUIPMENT WANTED. Don't wait — we'll pay cash for LATE MODEL HP, Tek, etc. Call Glenn, N7EPK, at Skagitronics Co. (800) 356-TRON.

FOR SALE: Ham Radio Ten-Tec solid state, Model 540, 200 watt transceiver, AC/DC power supply. John Spencer, Fairmont, MN 56031 (507) 238-1621.

DIGITAL AUTOMATIC DISPLAYS. All Radios. GRAND SYSTEMS, POB 2171, Blaine, Washington 98230.

MOTOROLA T45 RTA 860 MHz Trunking $450. Several H23, H33, HT 220's VHF low split $100 each. Scott (801) 224-3783.

ANTENNA SPECIALISTS—Astron, Decibel Products, Newmar, Ritron, Shure, TPL, Tripplite, Uniden/Bearcat, Valor. Dealer cost plus 10%. DW COMMUNICATIONS. (602) 669-2483

TEN-TEC, Now shipping new boxed latest models 1988 production USA made, 585 Paragon, 561 Corsair II, 229B Antenna Tuner, 425 Titan 1.5 KW amplifier, new model 1 KW Hercules II Mobile/Base Amplifier, 2510 satellite station, TT920 aviation airband HT plus accessories all models. For best deal write or phone Bill Slep (704) 524-7519. SLEP ELECTRONICS COMPANY, Highway 441, Otto, NC 28763.

HAMLOG COMPUTER PROGRAMS. 17 modules auto-logs, sorts 7-band WAS/DXCC. Full features. Apple $19.95, IBM or CP/M $24.95. KA1AWH, POB 2015, Peabody, MA 01960.

CALL SIGN BADGES: Custom license plate holders. Personal, distinctive. Club discounts. SASE. WB3GND, Box 750, Clinton, MD 20735. (301) 248-7302.

R-390A RECEIVER PARTS: Info SASE. CPRC-26 military Manpack Radio, 6 meter FM, with antenna, crystal, handset: $22.50, $42.50/pair, $97.50/six. Military-spec TS-352 Voltohm/Multimeter, leads, manual: $12.50. $4.50/piece shipping, $9 maximum. Baytronics, PO Box 591, Sandusky, OH 44870.

75A-4, NC303 WANTED. State model, condition, price and telephone. Bob Mattson, KC2LK, 10 Janewood, Highland, NY 12528.

AM TRANSMITTER WANTED. State model, condition, price and telephone. Bob Mattson, KC2LK, 10 Janewood, Highland, NY 12528.

FOR SALE: Kenwood TS-820S, digital display. Excellent condition, very clean. $475. Matt, WA1HRE, (203) 693-0468.

PROFESSIONAL QUALITY DTMF Decoder and Select Call System, by Vince Yakamavich, AA4MY, see Feb QST Magazine for details. Blank board #152-PCB only $17.95. Kit of Parts including board, #152-KIT only $69.95. Assembled and tested board #152-ASY only $99.95. Add $2.50 per order S/H. A & A ENGINEERING, 2521 W. LaPalma, Unit K, Anaheim, CA 92801. (714) 952-2114.

WANTED Rohn 25G sections (5 or more), guys, guy grips, turnbuckles, insulators, etc. LDF5-50 heliax plus connectors up to 250 ft. Will pick up within 150 miles of Huntsville, AL. HAM-M or Ham-VI will pay shipping. Robert Walls, 128 Dollywood Drive, Toney, AL 35773 (205) 828-6738.

PROGRAMMER for single component microcomputer. Learn to program, control circuits, generate wave forms. SASE details. DELL COMMUNICATIONS, 538 Griscom Drive, Woodbury, NJ 08096.

SB220 OWNERS: Add 160 meters, QSK, +8 additional enhancements. 40 page step by step manual includes parts sources, and 3-500z tech manual. SASE for details. $10 plus $1 postage. WA2SQQ, 69 Memorial Place, Elmwood Park, NJ 07407.

ANALOG AND RF CONSULTING for the San Francisco Bay area. Commercial and military circuits and systems. James Long, Ph.D., N6YB (408) 733-8329.

COMMODORE/AMIGA CUSTOM CHIPS FOR C64/128 Computer/peripherals at low prices. 24 hour delivery. #6510- $9.95, #6526- $9.95, #6567- $14.75, #6581- $12.85, PLA- $12.50, 901 ROMS at $10.95 each and many others, including Amiga..."The COMMODORE DIAGNOSTICIAN". A complete diagnostic reference chart for fixing Commodore computers, etc. An absolute must for those who want to fix their own computers and save money and downtime. $6.95 plus $1.00 postage.. COMMODORE REPAIR. We are the largest/oldest Authorized Service Center in the country. (eg. C64- $39.95). Fast turnaround. Heavy duty Power Supply for C64- $27.95 plus UPS. Send for complete chips/parts catalog...VISA/MC...Kasara, Inc, 36 Murray Hill Drive, Spring Valley, NY 10977. 1-800-642-7634, 800-248-2983 (outside NY) or 914-356-3131.

WANTED: Klystron tubes especially 2911; Magnatrons; also 304TL, 6012, 810 and 5CX1500A. All types of sockets for transmitting tubes. Harold Bramstedt, 6104 Egg Lk Rd, Hugo, MN 55038. (612) 429-9397.

UHF PARTS. GaAs fets, mimics, chip caps, trimmer caps, and other builder parts. MGF 1402 @$14.00. MFG 1302 @$10.00. .8-10pf Trimtronics trimmer @$3.75. Porcelain chip caps @$1.75. Orders add $1.00 p+h. SASE for complete list. MICROWAVE COMPONENTS, 11216 Cape Cod, Taylor, MI 48180.

WA9GFR COMMUNICATIONS SOFTWARE. $15.00 disk contains HF/VHF/UHF/L-Band propagation programs to predict range in miles based on transmitter power, receiver sensitivity, and antenna height & gain. A "must" for designing repeater installations. Also includes Smith Chart impedance matching programs. Commodore-64 or IBM. Lynn Gerig, RR1, Monroeville, IN 46773.

BM-PC RTTY/CW. New CompRtty II is the complete RTTY/CW program for IBM-PC's and compatibles. Now with larger buffers, better support for packet units, pictures, much more. Virtually any speed ASCII, BAUDOT, CW. Text entry via built-in screen editor! Adjustable split screen display. Instant mode/speed change. Hardcopy, diskcopy, break-in buffer, select calling, text file transfer, customizable full screen logging, 24 programmable 1000 character messages. Ideal for MARS and traffic handling. Requires 256k PC or AT compatible, serial port, RS-232C TU. $65. Send call letters (including MARS) with order. David A. Rice, KC2HO, 25 Village View Bluff, Ballston Lake, NY 12019.

JENNINGS UCS-300-7.5 KV variable vacuum capacitor $135, RJ1A/HC-1 vacuum relay $75, RJ2C $140. Cardwell 2100pF-3 KV variable capacitor $45. Eimac 3CX1200A7 $375, 4CX3,000A $675, 4CX5,000A $950, SK-2210/SK-2216 $85. Centralab 858-1000pF $5 ea. (All new). A. Emerald, 8956 Swallow, Ftn. Vly, CA 92708 (714) 962-5940.

RTTY JOURNAL—Now in our 36th year. Read about RTTY, AMTOR, PACKET, MSO'S, RTTY CONTESTING, RTTY DX and much more. Year's subscription to RTTY JOURNAL $10.00, foreign slightly higher. Order from: RTTY JOURNAL, 9085 La Casita Ave., Fountain Valley, CA 92708.

IMRA International Mission Radio Association helps missionaries. Equipment loaned. Weekday net, 14.280 MHz, 1-3 PM Eastern. Nine hundred Amateurs in 40 countries. Rev. Thomas Sable, S.J., University of Scranton, Scranton, PA 18510.

MARCO: Medical Amateur Radio Council, Ltd, operates daily and Sunday nets. Medically oriented Amateurs (physicians, dentists, veterinarians, nurses, physiotherapists, lab technicians, etc) invited to join. Presently over 550 members. For information write MARCO, Box 73's, Acme, PA 15610.

RUBBER STAMPS: 3 lines $5.00 PPD. Send check or MO to G.L. Pierce, 5521 Birkdale Way, San Diego, CA 92117. SASE brings information.

ELECTRON TUBES: Receiving, transmitting, microwave... all types available. Large stock. Next day delivery, most cases. DAILY ELECTRONICS, PO Box 5029, Compton, CA 90224. (213) 774-1255.

CUSTOM MADE EMBROIDERED PATCHES. Any size, shape, colors. Five patch minimum. Free sample, prices and ordering information. HEIN SPECIALTIES, Inc., Dept 301, 4202 N. Drake, Chicago, IL 60618.

RECONDITIONED TEST EQUIPMENT $1.25 for catalog. Walter, 2697 Nickel, San Pablo, CA 94806.

COMING EVENTS

Activities — "Places to go . . ."

SPECIAL REQUEST TO ALL AMATEUR RADIO PUBLICITY COORDINATORS: PLEASE INDICATE IN YOUR ANNOUNCEMENTS WHETHER OR NOT YOUR HAMFEST LOCATION, CLASSES, EXAMS, MEETINGS, FLEA MARKETS, ETC, ARE WHEELCHAIR ACCESSIBLE. THIS INFORMATION WOULD BE GREATLY APPRECIATED BY OUR BROTHER/SISTER HAMS WITH LIMITED PHYSICAL ABILITY.

OHIO: April 29. The 19th Annual B*A*S*H will be held on Friday night of the Hamvention at the Conference Center (Madison Room) of the HARA ARENA AND CONFERENCE CENTER, (the same location as the Hamvention), starting at 7:00 PM. There is no admission charge, and free continuous entertainment. Hot dinner, sandwichs, snacks and beverages are available. Two exciting top awards, and many others. Stay right at HARA when the Hamvention closes on Friday evening and meet your friends and join us for an evening of fun and entertainment. Sponsored by the Miami Valley F.M. Association, PO Box 263, Dayton, Ohio 45401.

ARIZONA: April 30-May 1. The Cochise Amateur Radio Association (CARA) will hold its 1988 Hamfest at the club's training facility, south Moson Road and Rt 90, Sierra Vista. VE exams, free tailgating. Talk in on 146.16/76 or 146.52. For more information contact Steve Wagner, W7CI (602) 458-6946 or CARA, PO Box 1855, Sierra Vista, AZ 85636.

FLORIDA: May 8. SPARC, the St. Petersburg ARC is sponsoring a Hamfest. Lake Maggiorie Park, Shelter 1 and 2, Ninth Sts and Lake Maggorie, St. Petersburg. 8 AM to 3 PM. Free admission. Free swap tables. Talk in on 147.06/66. Contact Hank Briese, WA4RLV, 10804—84th Avenue N., Seminole, FL 34642.

OHIO: May 8. Medina County Hamfest, sponsored by the Medina 2 Meter Group. 8 AM to 2 PM. Medina County Community Center, 735 Lafayette Road, Medina. Donations $4.00/door; $3.00/advance. Vendor tables $6.00. Setup 6 AM. Mobile check in 147.63/03 K8TV/R. Free parking. Medina Hamfest Committee, PO Box 452, Medina, OH 44258.

OKLAHOMA: May 14 and 15. The 1988 Green Country Hamfest, sponsored by the Broken Arrow and Tulsa ARCs, Tulsa State Fairgrounds Pavilion. 9 AM to 5 PM Saturday and 8 AM to 4 PM Sunday. All indoors flea market and dealer exhibits, programs, exams. Nearby Amusement Park. Evening family BBQ affordably priced at $7.00. Blue Grass band entertainment. Preregistration $6. $8 at the door. Flea market tables $7.50 advance; $10/door. Children under 12 free. For information contact Ron Gamel, N5WX (918) 663-0385 or write Green Country Hamfest, PO Box 4283, Tulsa, OK 74159.

ILLINOIS: May 15. The Knox County Radio Club will hold its annual Knox County Hamfest, Knox County Fairgrounds, Knoxville. Large outdoor flea market area space available at no charge. Opens 7 AM. Indoor commercial opens 8 AM. VE exams on site. Knox County Pork Producers will serve their famous Butterfly pork chops and more. Talk in on 147.00/146.40. For table reservations, exam registration and tickets write Keith L. Watson, WB9KHL, 119 South Cherry Street #3, Galesburg, IL 61401-4527 or call (309) 342-3885 evenings.

OHIO: May 15. The Athens County Amateur Radio Association's ninth annual Hamfest, City Recreation Center, East State Street, Athens. 8 AM to 3 PM. Admission $4.00. All level license exams. Send completed 610, $4.55 check payable to ARRL/VEC to John Cornwell, NC8V, 101 Coventry Lane, Athens, Ohio 45701. Walkins accepted. Free paved flea market. Indoor space advance registration only. Contact Rod Holley, KA8NDC, 15267 S. Canaan Rd, Athens, Ohio 45701. (614) 593-8177. Talk in on club repeater 146.34/.94. For general information Carl J. Denbow, KA8JXG, 63 Morris Avenue, Athens, Ohio 45701.

NEW YORK: May 15. LIMARC ARRL Long Island Hamfair, New York Institute of Technology, Rt 25A/Northern Blvd, Old Westbury, NY. Outdoor tailgating $5.00/car space. General admission $3.00. Non-Ham spouse and children admitted free. Open 7:30 AM for sellers; 9 AM for buyers. Food, refreshments available. For more information call Hank Wener, WB2ALW (516) 484-4322 or Mark Nadel, NK2T (516) 796-2366.

ILLINOIS: May 15. Chicago ARC's annual Mini-Hamfest, North Park Village, 5801 N. Pulaski, Chicago. Admission $2. 9 AM to 3 PM. Refreshments. For information call 545-3622.

PENNSYLVANIA: May 15. The Warminster ARC's 14th annual Hamfest, Middletown Grange Fairgrounds, Penns Park Road, Wrightstown. Gates open 7 AM. Vendors 6 AM. Admission $3.00. Indoor 8' tables $5.00/space. Unlimited outdoor space $5.00/space. Talk in 146.52 simplex. 147.69/09 repeater. For information or pre-registration contact Frank Charlton, KA3FBP, 1479 Kingsley Drive, Warminster, PA 18974. (215) 675-2549.

PENNSYLVANIA: May 15. 10th annual Hamfest sponsored by the Tioga County Amateur Radio Club, Tioga County Fairgrounds, Whitneyville. 8 AM to 4 PM. Gate admission $3.00. Advance $2.50. Inside tables $3.00. Outdoor flea market free. VE testing. For advance tickets send check or MO with #10 SASE to Bill Reilly, RD 4, Box 103, Wellsboro, PA 16901. Deadline May 1, 1988. Talk in on 146.79 or 146.52 simplex. For more information John Winkler, WB3GPY, RD 2, Box 267, Wellsboro, PA 16901.

ILLINOIS: Kankakee. May 15. The annual Kankakee Hamfest, sponsored by the Kankakee Area Radio Society will be held at the Kankakee County Fairgrounds from 8 AM to 3 PM. Free flea market tables (limited) and many exhibitors. ARRL Booth. Free parking. Food and drinks available. Admission $2.50 advance, $3.00 at the door. Setup May 14 6 PM to 8 PM and May 15 6 AM to 8 AM. Talk in on 146.34/94. More information from KARS c/o *Frank DalCanton, KA9PWW, RR 1, Box 361, Chebanse,* Illinois 60922. Tel 815-932-6703 after 5 PM CST or 815-937-2452 before 5 PM CST.

MICHIGAN: May 21. Swap & Shop sponsored by the Wexaukee ARC. NEW LOCATION- Cadillac Middle School, 500 Chestnut Street, Cadillac. 8:30 AM to 3 PM. Admission $3.00. Tables $6.00. Guest speaker, Doug DeMaw, W1FB. Contact John Craddock, KX8Z (616) 797-5491 or write Wexaukee ARC, PO Box 163, Cadillac, MI 49601.

COLORADO: May 21. The Pikes Peak Radio Amateur Association's Swapfest, Rustic Hills Mall, Palmer Park and Academy Blvd, Colorado Springs. 8:30 AM. Free admission. Tables $8.00/advance; $10.00/door. VE exams. Talk in on 146.37/97. For information or reservations contact Al, N0CMW (303) 473-1660 or write PPRAA Swapfest, PO Box 16521, Colorado Springs, CO 80935.

TEXAS: May 21. Armed Forces Day. The Key City ARC will hold its annual Ham Radio/Computer Swapfest, Abilene Civic Center, Pine Street, downtown Abilene. 8 AM to 5 PM. Friday night 6 to 11 PM Dealer Setup. Pre-registration $5; $6/door. Tables $2.00 each. Non-ham spouses and children under 12 admitted free. Ham breakfast Saturday morning 6 AM to 7:45 AM. Texas Bar-B-Que 7:30 PM, Abilene Inn. FCC exams. Talk in on 146.800. For information contact Bill Jones, N5DOX (915) 698-4606. Send pre-registrations to RCARC, Box 2722, Abilene, TX 79604 or call me on 14.090 RTTY during the day.

NEBRASKA: May 20, 21, 22. The 1988 Midwest Division ARRL Convention, Marina Inn, So. Sioux City. Friday night get-acquainted dinner with entertainment. Saturday activities start 8 AM. Exhibitors and large flea market. DX, Packet, Computers, Handi-Hams, RTTY, AMTOR. FCC exams Sunday AM. Flea market info Al Smith, W0PEX, 3529 Douglas St, Sioux City, Iowa 51104. Convention info Dick Pitner, W0FZO, 2931 Pierce St, Sioux City, Iowa 51104.

ARKANSAS: May 21. The Northwest Arkansas ARC's annual Hamfest, Rodeo Center, East Emma Avenue, Hwy 68B, Springdale. 8 AM to 4 PM. Setup 6 AM. Exhibits, swap tables, snack bar, VEC exams, forums, programs, etc. Reserved tables $3.00 each. Talk in on 146.76. For information or tables contact Chuck Webb, KA5BML or Mary Webb, KA5HEV, PO Box 338, Prairie Grove, AR 72753. (501) 846-2847.

NEW HAMPSHIRE: May 20-22. The 14th Annual Eastern VHF/UHF/SHF Conference, Rivier College, Nashua. Sponsored by the Northeast VHF Association. Chairman Thomas Kirby, W1EJ. Friday night hospitality room including swap-fest, tech talks on Saturday. Housing available in dormitories. For information, reservations, etc contact Lewis D. Collins, W1GXT, Publicity Chairman, Eastern VHF/UHF/SHF Conference, 10 Marshall Terrace, Wayland, MA 01778. (617) 358-2854 (6 to 10 PM EST)

NEW YORK: May 27 and 28. The 2nd annual SKANFEST, Ham Radio and Computers, Allyn Arena, Skaneateles. Indoor/outdoor setup Friday, Noon to 6 PM. Open Saturday 9 AM to 5 PM. Flea markets, indoor commercial vendors, tech sessions and more. Advance admission $2.50, gate $3.00; outdoor flea market $2.50/space; gate $3.00; indoor flea market $8.00/8' table; gate $10.00. Talk in on 147.00/146.40 and 442.30 repeaters. For more info call Hank Bryant (315) 685-7658. Advanced tickets SKANFEST, PO Box 302, Skaneateles, NY 13152. Deadline May 13.

ONTARIO: June 4. Amateur Radio Flea Market sponsored by the Guelph ARC and the Kitchener-Waterloo ARC, Bingeman Park, 1380 Victoria Street North, Kitchener. 8 AM to 2 PM. Vendors 6 AM. Admission $3.00. Children 12 and under admitted free. Vendors table rentals $5/8' space. Talk in on 146.37, 146.97, 144.61, 145.21, 52/52 simplex. For tickets or table reservations contact Ray Jennings, VE3CZE, Co-Chairman, 61 Ottawa Crescent, Guelph, Ontario N1E 2A8 (519) 822-8342.

MICHIGAN: June 5. The 11th annual Chelsea Swap 'N Shop, Chelsea Fairgrounds. Donation $2.50 advance; $3.00/door. 8' table space $8.00. Trunk sales $2.00/space. Handicap parking. Food available. Nearby campgrounds. For information Robert Schantz, 416 Wilkinson Street, Chelsea, MI 48118. (313) 475-1795.

CONNECTICUT: June 5. The 4th annual NARL Flea Market, sponsored by the Newington Amateur Radio League, Newington High School, Rt 173, Newington. Tours of ARRL Headquarters and W1AW, exams, refreshments. Ham and computer gear for sale. Talk in on 146.52, 144.85/5.45 and 223.24/4.84. For information SASE to Les Andrew, KA1KRP, 23 Grove St, West Hartford, CT 06110. (203) 523-0453.

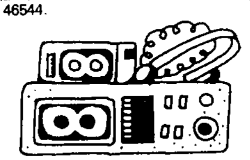
PENNSYLVANIA: June 5. The 34th annual Breeze Shooters Hamfest, White Swan Amusement Park, Rt 60, near Greater Pittsburgh International Airport. 9 AM to 4 PM. Free admission, free parking, free tailgating. Family amusement park. Registration $2.00 each; 3/$5.00; 7/$10. For additional information call Jim Inverarity, K3TOQ, 2639 Sunnyfield Drive, Pittsburgh, PA 15241. (412) 833-2681.

VIRGINIA: June 5. Manassas. The Ole Virginia Hams present the annual Manassas Hamfest and Computer Show the the Prince William County Fairgrounds. 8 AM to 4 PM. General admission $5.00. Children under 12 admitted free. Tailgating $5.00/space. Special activities include non-ham programs, ARRL booth and CW proficiency awards. Talk in on 146.37/97, 146.52. Dealers contact Joe Schlatter, K4FPT (703) 368-8599 evenings or Randy Moler, KA4UFF (703) 791-3061. For information write Ole Virginia Hams ARC, PO Box 1255, Manassas, VA 22110 or call Jack Gunsett, KI4VP (703) 361-5255.

COLORADO: June 10 and 11. The tenth annual Superfest sponsored by the Northern Colorado ARC, Larimer County Fairgrounds, Loveland. 5 PM to 9 PM Friday and 8 AM to 5 PM Saturday. Dealer setup all day Friday. VEC exams Saturday. Refreshments available both days. For information contact Exhibits Chairman Bud Hayes, W0JFN, 3109 N. Douglas, Loveland, CO 80537 (303) 663-3119.

NORTH CAROLINA: June 11. Winston Salem Hamfest & Computer Electronics Fair '88. Sponsored by the Forsyth ARC. Dixie Classic Fairgrounds, Winston-Salem. Admission $4/advance; $5/door. Food, indoor dealer area. FCC exams. Contact Bob Gates, KJ4IC, Box 60, Cedar Grove Park, Kernersville, NC 27284. Plenty of flea market/tailgating space and free parking. Talk in on 146.04/64. For pre-registration SASE to Dave Ward, KA1LVO, 5573 Vienna-Dozier Rd, Pfafftown, NC 27040. Dealer info Jim Rodgers, N1DRI, Box 11234, Winston-Salem, NC 27116 (919) 760-2493).

INDIANA: June 12. "Summerfest" sponsored by the Michiana ARC, University of Notre Dame Athletic and Convocation Center, South Bend. Exhibits, FCC exams—walkins, shows. For reservations or information call Joe Mergen, N9GID (219) 258-0057 or (219) 258-0577. Write to: 2030 Trailridge North, Mishawaka, IN 46544.



OPERATING EVENTS

"Things to do . . ."

May 14. SARA will operate K2AE from Saratoga Spa State Park, Schenectady during the Boy Scouts of America North-O-Ree III. 1300 to 2000Z. 14.330 and 28.360. For commemorative QSL send QSL and SASE to WB2STS, 2 Union Street, Schenectady, NY 12305.

May 14 and 15. The Uniontown ARC will operate W3PIE, 1700 to 0300Z both days to commemorate the 50th anniversary of U.A.R.C./W3PIE. For certificate send QSL and large SASE to Uniontown ARC, c/o John Cermak, Box 433, Republic, PA 15475.

May 21: The 39th annual Armed Forces Day Communication Test. CW, SSB, RTTY and Packet.

May 21: The Maryland Mobileers ARC will again operate its annual Special Events Station aboard the U.S. Submarine Torsk, Pier 3, Baltimore Inner Harbor. 9:30 AM to 4 PM EST. The Mobileers have chosen Armed Forces Day to honor the Submarine Service. The public is invited to come aboard and watch the Hams in action.

May 21-22: The St. Charles ARC will operate Special Event Station WB0HSI from 1300Z to 2100Z as part of the Lewis and Clark Rendezvous. 7250, 14325, 21350, 28410 and 146.67. For certificates send large SASE to the St. Charles ARC, PO Box 1429, St. Charles, MO 63302-1429.

May 21: The Great River ARC of Dubuque, Iowa will operate NS0U from 1500Z to 220Z at the site of the annual Dubuquefest Special Events and Message Center. Lower 20 kHz of 75, 40, 20 and 15m General bands. Novice band station N9FVN voice 10m. For QSL card SASE to NS0U, 2735 Hickory Hill, Dubuque, Iowa 52001

May 28-June 3. The Palmetto ARC will operate club station W4MN as W2OOMN to celebrate the Bicentennial of the US Constitution from the historic South Carolina state capital, Columbia. Operation on all bands with SSB, CW and RTTY during this week. For a special commerative QSL send large SASE and QSL via W4MN, Palmetto ARC, 625 Spring Lake Rd, Columbia, SC 29206.

May 28: Members of the Bay Area ARS will operate Special Event station N3EKZ to commemorate the transmission of the telegraph message, "What Hath God Wrought" send on an experimental line from Washington to Baltimore 144 years ago. For a special commemorative certificate send QSL card, SWL send details of QSO, with large SASE to the Bay Area ARS, PO Box 805, Pasadena, MD 21122-0005.

June 6 to June 12: The Ascension Amateur Radio Club will hold its annual Jambalaya Festival Special Event, 1500Z to 2359Z daily on 20, 15 and 10m bands. Special event package contains three Jambalaya Recipes. Send $1.00 to cover postage and mailers, QSL card with calls of stations worked to AARC, PO Box 278, Sorrento, LA 70778-0278.

THE FOUNDATION FOR AMATEUR RADIO, INC plans to award twenty-eight scholarships for academic year 1988-89 to assist licensed Radio Amateurs who plan to pursue a full-time course of study beyond high school and are enrolled or have been accepted by an accredited university, college or technical school. For further information write FAR Scholarships, 6903 Rhode Island avenue, College Park, MD 20740 prior to May 31, 1988.

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ELMER's NOTEBOOK

Tom McMullen, W1SL

This is antenna month, both in *ham radio* magazine and in backyards all across the country. For many Amateurs, it's a time to try some of the ideas that were chewed over during the cold, short days and long nights of the past winter. For others, it's a time to assess the skywire's readiness to start on the next season's DX or rag-chewing. Whatever the reason, antennas are an endlessly popular subject in Amateur Radio circles, so I'll add a few thoughts.

ideal antennas

There are certain truisms in the radio world that are hard to argue with: "a big antenna is better than a small one," or, "a high antenna grabs DX better than a low one," and "a rotary beam antenna is more versatile than a fixed dipole."

Along with these truths is the feeling that one should have limitless backyard acreage available in which to put these marvels of wire, insulation, tubing, and tower. Does a ham exist who hasn't dreamed of two perfectly spaced tall trees that an 80 (or 40, 160, or whatever) meter dipole will fit between nicely? Or how about that sight for sore eyes, the 100+ foot tower gleaming in its nest of guy wires with half of Alcoa's stock of tubing on the top, waiting to whirl to a bearing for that rare one? Sad to say, far too many hams are faced with the same pressures for space as the rest of the population. In many parts of highly populated urban America, real estate people tout 70 by 130 feet as a "large" lot! And it usually has power lines across one or both ends; this further reduces the options for antenna-izing.

antennas for the real world

The view is not too bleak, however. Amateur Radio can and does thrive in cramped neighborhoods — some that, by comparison, make 70 by 130 seem like a really large lot.

A look at a few antenna fundamentals will help you find a way to put up a working skywire.

First, note that the portion of the antenna that carries the heaviest current does the work. Current flow, whether dc, ac, or rf, is the major energy-transfer medium. With an ideal center-fed antenna, placed high in the clear, the current flow in the center produces a magnetic field that surrounds the wire. If you could see the rf, a sight down the wire from one end would show you a doughnut-shaped field expanding in all directions. Anything above the horizon would keep on going out of sight, and the field that intercepts the earth (or houses, wiring, and trees) would bend and reflect in ways that are sometimes difficult to predict.

A vertical antenna (like a quarter wave with many ground radials at its base) also has a magnetic field around it, but the "doughnut" is on its side at the base of the antenna — and much of it actually intercepts the earth and ground system. It is this interception and reflection from nearby "ground" that cause a large portion of the radiation to depart the vicinity at a considerable angle above the horizon. Not to worry: the atmosphere is full of layers of ionized gas just waiting to bend the waves back down to earth, and often there's another Amateur at the other end of the specific ray path!

Much can be done with these simple antennas if you remember some basics: the high-voltage end(s) must be well insulated; and any vertical, especially the shorter ones, must have a ground system of some sort to work against. Let's look at a few examples.

the nonhorizontal dipole

This type of antenna, shown in **fig. 1**, has been called a "sloper" in many publications. It is simply a center-fed half-wave antenna suspended between two convenient supports (in this case, the top of a house and a section of mast anchored to a fence post). The high end can be anything you can reach to hook the antenna on — a tree, an attic window, a telescoping tower made of tubing sections, whatever. *Never, never* use any part of nearby power line poles for your support! All antenna installations should be carefully planned so there's no chance of any accidental contact with power wiring; that includes the entrance wiring to your house.

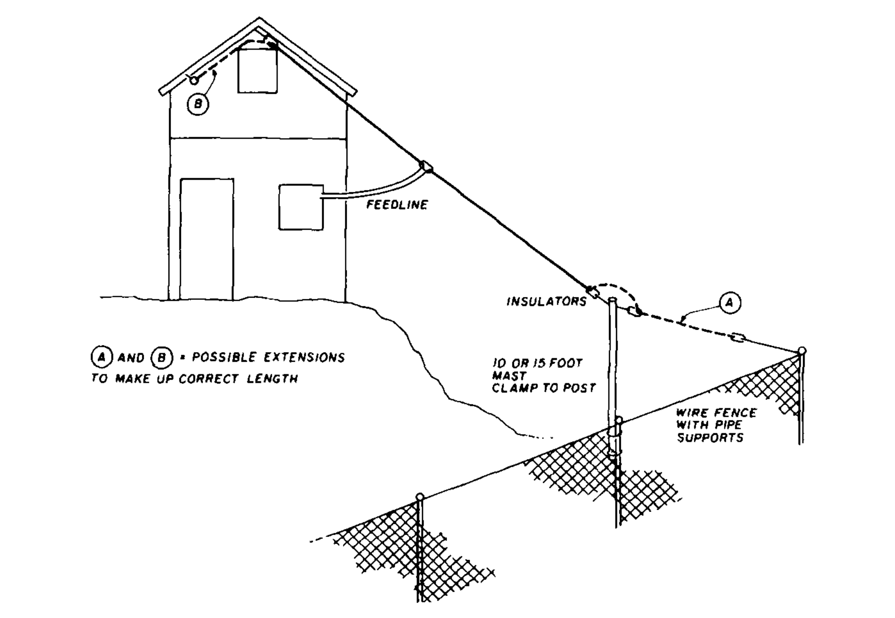

fig. 1. An antenna can be suspended between a tall object, such as a roof peak or high window, and a lower one that is a convenient distance away. Extensions can be added to gain a few more feet if needed, as shown by dotted lines A and B.

The antenna in **fig. 1** is center fed with either a coaxial cable and a balun, or by twin lead. If you use twin lead or ladder line, you'll need either a Transmatch or a balun transformer at the transmitter end to provide a balanced feed.

You have a couple of options if the space is too short to support a half-wave antenna on the band you want to operate. Putting in some loading coils will physically shorten it while still providing an electrical half wave. These coils make the antenna resonant, so it will absorb and radiate power almost as well as if it were full length. Many antenna manuals and handbooks describe how to make simple loading coils wound around porcelain insulators or plastic rods, but you can find them in magazine advertisements or at hamfest flea markets.

Another option is to bend the antenna a bit. You'll want to support as much of the current-carrying part of the wire as high and clear as possible, and let the ends run off at the angle necessary to make up the correct length — the shallower the angle, the better. Don't let it bend back on itself because fields from parallel wires tend to cancel. If you can get from a half to three-quarters of an antenna suspended straight between supports, it will perform almost as well as if the whole thing were in a straight line.

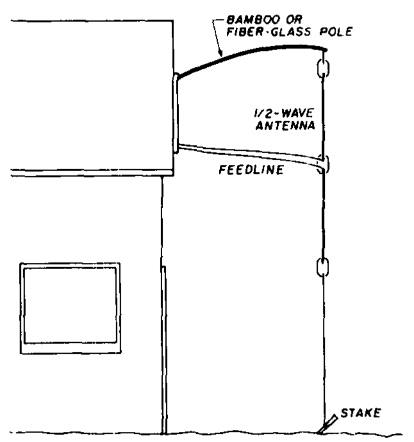

fig. 2. A dipole hung from a fishing-pole out of a high window is a quick solution for a 1-meter requirement. You can use light-gauge wire and small insulators here, and RG-58A-U is fine for short feedline runs.

The radiation pattern (that "doughnut" mentioned earlier) will not be ideal from antennas that slope or zigzag around the lot between supports; but they'll work, and will snag a surprising number of contacts for you.

It's great if you can increase the height of the lower support, but you *can* put up a relatively inexpensive, easy-to-install antenna between convenient supports. You'll enjoy lots of QSOs while waiting for that magic day when you can afford a pair of great towers on a zillion-acre lot with no neighbors within miles.

a vertical dipole

Figure 2 shows another way to use a half-wave antenna. This one is especially useful on 10 meters, a band that will be really hopping now that Novices have voice and digital privileges on it. The idea is simplicity itself: just stick the longest bamboo (or glass fiber) fishing pole you can find out of your highest window, and hang an antenna from the end of it. Try it and join the fun without investing in a lot of hardware!

Keep the antenna as high as possible for two reasons: it will perform better, and will keep the "hot" end from the reach of curious bystanders. (Those rf burns are nasty, and heal very slowly!) Again, the feed can be either coaxial cable or twin lead.

The antenna will still work if your house has metal siding, but will show some VSWR on the line and radiate most of its power away from the house. You can adjust for the VSWR problem with a Transmatch, or change the length of the elements very slightly to get rid of it. Start with the antenna a few inches longer than called for by the formula, and remove an inch at a time from each end until the VSWR gets down to a level that's right for your equipment.

a quarter-wave antenna

Because of its size, a quarter-wave antenna has many possible mounting schemes. That same chain-link fence that helps anchor the mast for a "sloper" can serve as a ground system for a quarter-wave vertical (see **fig. 3**).

Adapt some mobile-mounting hardware to clamp the base to the posts or top railing, run some coax across the lawn, and plug it in. Height helps, but not as much as you might think, especially on a wide-open 10-meter band. A vertical for 15 meters is still within reason for this type of mount, but you'll need a rugged fence and plenty of strong tubing to make it work for 40 meters. A shortened 40-meter quarter-wave antenna does work, however. It can be made with a loading coil at the base and a capacitive "top hat" that achieves resonance with physical lengths as short as one-eighth wave or less. Be aware; this "shorty" is a very fussy, high-Q device that requires retuning if you move your frequency very far. The feedpoint impedance is often very low, and needs a good matching circuit and large wires to carry the higher current without loss.

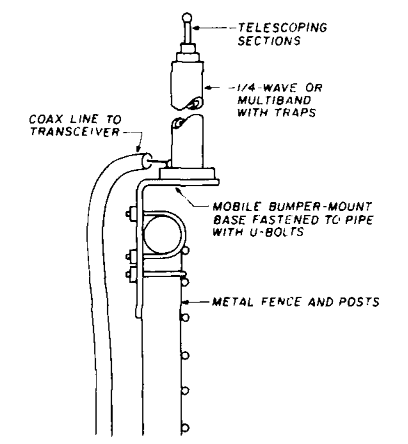

fig. 3. A metal fence support structure or porch/balcony railing can serve as a ground system and support for vertical 1/4-wave antennas or a multi-band vertical. A modified mobile bumper mount can be clamped to the posts or railing.

the multiband antenna

Many Amateurs, beginners and old-timers alike, rack up a respectable number of QSOs each year using vertical antennas built to work on several bands. Most of the available "all-band" antennas now include the new frequencies gained at the recent WARC conferences. This type of antenna is constructed of aluminum tubing with trap circuits placed at various spots along its length. It is fed with coaxial cable, and once mounted and adjusted for proper operation, needs no further attention. Just switch your transmitter to whatever band you want; the antenna is ready. Many excellent antennas are advertised in magazines, and you can often get a bargain on a used one when someone upgrades his system.

The vertical multiband antenna also requires a ground to work against, and the fence comes to mind once more. Alternatives are a metal balcony or porch railing, galvanized pipe driven into the ground, or a roof peak with several wire "radials" fanning out from the mounting hardware.

Don't ignore the metal rain gutters around your house. They are often enemies because they reflect or absorb energy from a nearby antenna, but they can be friends as well. Use them as additional "ground plane" for a roof-mounted antenna. If not attached to metal siding, they can even be loaded up to serve as an antenna. (The radiation pattern will be strange, and you'll have rf on the bathroom fixtures, but it will work!)

"Verticals" needn't be exactly vertical. I read about a vacationer who carried a collapsible multiband vertical in his luggage. He simply assembled the sections and clamped the base to the hotel balcony railing, tilting the antenna at whatever angle was needed to clear the balcony above. He made many exciting contacts in faraway places with this bit of ingenuity.

So don't mourn for the lack of an ideal location. If you can stick up a piece of wire or tubing, and make it the right length (or use traps or tuners to make your transmitter think it's the right length), it will work and you'll have a ball.

mounting tips

It is relatively easy to put up simple antennas, and most of them work well. But there are a few things that will turn a useful dipole into a bird roost. Don't let the ends of the antenna wander off into the bushes where branches and leaves can make contact with the wire. These ends are the most sensitive parts of an antenna, and a water-laden limb or bunches of leaves will have the effect of putting a big resistor across the antenna — they will detune it and absorb power. If you must use a tree to support an antenna, clear all branches away from the wire.

Most trees do a lot of swaying in the wind, and it is best to plan for this at the beginning. Put some springs between the insulators and supports at both ends. I like to put at least two springs at the end that attaches to the tree, and one at the fixed-support end. Use springs that compress under tension. (A screen-door spring that stretches will eventually fatigue to the point where the antenna sags too much.) Don't try to pull the antenna so tight that it resembles a guitar string. Give it enough slack that temperature variations and wind sway won't break anything.

what length?

Here are a few formulas to help you decide if you have enough room between supports to put up an antenna, or to measure the tubing or wire needed.

For a half wave in free space:

$$\text{length (feet)} = \frac{492}{f(MHz)} \qquad (1)$$

for an antenna made of wire (most common):

$$\text{length (feet)} = \frac{468}{f(MHz)} \qquad (2)$$

for a quarter-wave wire antenna:

$$\text{length (feet)} = \frac{234}{f(MHz)} \qquad (3)$$

When an antenna such as a vertical quarter wave is made of tubing, the diameter-to-wavelength ratio is large enough that the length must be shortened from those derived from the wire antenna formula. Your best bet is to make the antenna out of telescoping sections and vary the length for best performance.

ham radio

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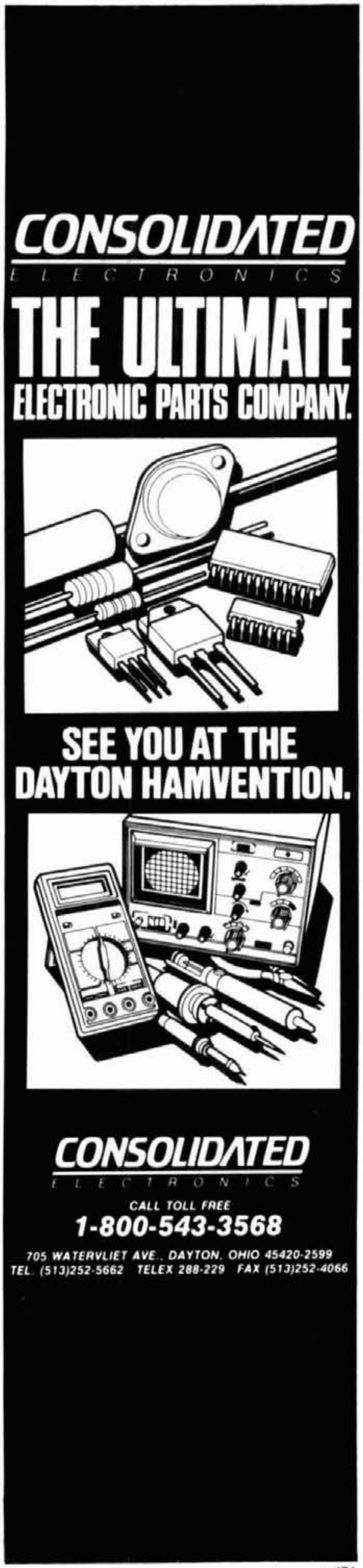

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8 LED DIGITS • 2 GATE TIMES
ANODIZED ALUMINUM CABINET
INTERNAL NI-CAD BATTERIES INCLUDED
AC ADAPTER/CHARGER INCLUDED

EXCELLENT SENSITIVITY & ACCURACY

AC-DC • PORTABLE OPERATION

#1200H 1.2 GHZ

Small enough to fit into a shirt pocket, our new 1.2 GHz and 1.3 GHz, 8 digit frequency counters are not toys! They can actually out perform units many times their size and price! Included are rechargeable Ni-Cad batteries installed inside the unit for hours of portable, cordless operation. The batteries are easily recharged using the AC adapter/charger supplied with the unit.

The excellent sensitivity of the 1200H makes it ideal for use with the telescoping RF pick-up antenna; accurately and easily measure transmit frequencies from handheld, fixed, or mobile radios such as: Police, firefighters, Ham, taxi, car telephone, aircraft, marine, etc. May be used for counter surveillance, locating hidden "bug" transmitters. Use with grid dip oscillator when designing and tuning antennas. May be used with a probe for measuring clock frequencies in computers, various digital circuitry or oscillators. Can be built into transmitters, signal generators and other devices to accurately monitor frequency.

The size, price and performance of these new instruments make them indispensible for technicians, engineers, schools, Hams, CBers, electronic hobbyists, short wave listeners, law enforcement personnel and many others.

STOCK NO:

#1200HKC	Model 1200H in kit form, 1-1200 MHz counter complete including all parts, cabinet, Ni-Cad batteries, AC adapter-battery charger and instructions	**$ 99.95**
#1200HC	Model 1200H factory assembled 1-1200 MHz counter, tested and calibrated, complete including Ni-Cad batteries and AC adapter/battery charger	**$137.50**
#1300HC	Model 1300H factory assembled 1-1300 MHz counter, tested and calibrated, complete including Ni-Cad batteries and AC adapter/battery charger	**$150.00**

ACCESSORIES:

#TA-100S	Telescoping RF pick-up antenna with BNC connector	**$12.00**
#P-100	Probe, direct connection 50 ohm, BNC connector	**$18.00**
#CC-70	Carrying case, black vinyl with zipper opening. Will hold a counter and accessories	**$10.00**

1.3 GHZ
#1300H

✓ 173

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Florida residents add 5% sales tax. COD fee $2.